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SCIENCE PROGRESS

RECENT ADVANCES

APPLIED MATHEMATICS. By PROF. F. E. RELTON, M.A., B.Sc., Royal School of Engineering, Giza.

Elasticity.—The question of the vibration and instability of rotating bodies has been the subject of numerous investigations, both theoretical and practical. Most of the latter are undertaken by commercial firms for a specific purpose connected with their industry, and their results are frequently not made public. The mathematician, the physicist, and the engineer are all called in to co-operate, and some of the optical and electrical methods of investigation which are ultimately evolved are highly ingenious. Up till quite recently I was myself engaged on a rather difficult problem of this type: a thin and easily deformable shell rotating at not inconsiderable speeds approaching 30,000 revolutions per minute. Thanks to my friend, Prof. Finch (of Everest fame), the variable condenser and cathode-ray oscillograph were pressed into service, with literally illuminating results.

The moral is that the mathematician cannot always expect to solve practical problems of this type by the unaided light of his own intelligence. Certain hypotheses and simplifications have to be made as a working basis; but practical work not merely indicates the reliability of the assumptions, it frequently reveals factors in operation whose presence might otherwise have been unsuspected. The rotor with which most of us are concerned is the shaft, and ordinary needs are met by some such work as Timoshenko's *Vibrations in Engineering*. When it comes to the higher flights, one has to go to original sources.

Much work has been done on the phenomenon of instability in a shaft rotating at certain critical speeds. Rather less attention has been devoted to the problem of vibration at non-critical speeds, though some years back there was much correspondence on the alleged presence of large vibrations at speeds $\Omega/2$ and $\Omega/\sqrt{2}$, where Ω is the first whirling speed. The problem of "shaft whipping" at speeds above Ω also attracted notice some time ago, and a theory was advanced

to account for it. The essence of this theory was that the instability was engendered by internal friction. The phenomenon itself seems incontestable; the explanation is more dubious.

The problem is tackled by Prof. R. C. J. Howland, *Phil. Mag.*, **76**, in a paper on "The Vibrations of Revolving Shafts." The viscosity of solids is not an easy matter; and though many writers on allied topics have found it convenient to use hysteresis effects, integrals over a time-cycle are difficult to absorb into differential equations. Howland uses a simplified form of a law suggested by Filon and Jessop, by assuming that the tension in an extending fibre is due partly to its extension and partly to its rate of extension. The solution of the resulting equation presents no difficulty, but it fails to solve the mystery, the clue to which probably lies in some of the neglected factors. The author makes no claim to finality, and suggests two likely quarters in which to seek; there is analytical (and probably experimental) work yet to be done. Incidentally the paper contains a slight misprint, the equality sign being elided from (2). In a later issue, No. 81, D. M. Smith, of Metrovics, calls attention to a slight misstatement and the author replies.

The same number of this journal contains a paper by B. Sen on "Stresses due to a Small Elliptic Hole or Crack on the Neutral Axis of a Deep Beam under Constant Bending Moment." The problem is treated as a matter of plane stress, so that the analysis can be conducted in terms of a single function. Elliptic co-ordinates are employed, by the usual transformation $x + iy = c \cosh(\xi + i\eta)$. No numerical results are supplied, but the quantitative results are what one would expect. From the lack of references one infers the author's unawareness that plane stress round elliptic holes has been previously discussed by others, notably in papers for the Institution of Naval Architects.

It is common practice in engineering to assume that the stress distribution can be regarded as plane. Much simplification is thereby ensured, especially if the linear law of distribution is superadded. One of the best-known results that follows from this is "the law of the middle third," which is so serviceable in civil engineering. An American writer, E. Kalman, in No. 77 of the same journal, writes on "Two-dimensional Linear Elastic States" and examines the implication of the linear relation, notably in its application to a beam and to dams.

The Castigliano brand of elasticity has latterly slumped somewhat, but the wheel is still receiving attention. No. 81 of the same journal has a paper by C. E. Larard, giving details of experiments that were performed testing the accuracy of

predictions made in a paper published last July. Those who are interested in the experimental side of elasticity might like to know that, according to J. Kuno, *Phil. Mag.*, **77**, phenolite is preferable for photo-elastic work to glass, celluloid, or even bakelite.

Hydrodynamics.—The *Phil. Mag.*, **77**, has a paper by C. E. Lemin on "The Motion of a Sphere through a Viscous Liquid." Stokes's original formula for the fall of a sphere in a viscous liquid has been modified from time to time by various writers. Some allow for a coefficient of sliding friction; others allow for the finiteness of the medium in which the fall occurs. The present paper is a record of experimental work to test Ladenburg's modification.

Closely allied to the falling sphere is the spherical bob of a pendulum. The same journal contains a paper by G. W. Brindley "On the Turbulent and Stream-line Damping of a Pendulum in a Viscous Medium." It appears that Stokes's theory is acceptable if the amplitudes are sufficiently small, the logarithmic decrement being then constant. Actually the logarithmic decrement becomes smaller as amplitudes decrease, large amplitudes requiring a turbulent damping and necessitating a v^2 – law. In all practical cases, the damping due to the suspension is such that it cannot be ignored. The subject received further treatment, in the preceding issue, at the hands of F. E. Hoare, "On the Damping of a Pendulum by Viscous Media." This is mainly occupied in comparing approximation formulæ with experimental results.

"Experiments on Cylinders Oscillating in a Stream of Water," by A. Thom, appears in No. 77. The cylinder is hung vertically in an horizontal stream of water and oscillates transversely. It will oscillate continuously if its natural period tallies with the rate of eddy-formation. As indicated by the title, the paper is mainly experimental, but naturally an attempt is made to link it up with the Karman vortex street.

Last November I published "The Steady Broadside Motion of an Anchor Ring in an Infinite Viscous Liquid," *Proc. Roy. Soc.*, 1931, **134**, 47. The analysis is conducted in orthogonal curvilinear ring-co-ordinates, coupled with a stream function. Assuming that the motion is slow enough to permit the ignoration of the inertia terms, the solution comes to depend on a fourth order partial differential equation. This I solved in Fourier form by the use of associated Legendre functions of degree half an odd integer. The usual stress- and rate-of-strain dyadics then lead to an expression for the resistance to the motion. At one time subsequently I had hopes that the computation of the associated Legendre functions would be undertaken by some representative body. It appears that

Bessel functions are now more likely to receive attention. Nor am I greatly surprised, for when one comes to examine the matter, not as much as one would expect is known about the associated Legendre functions.

The publication of this paper had various consequences. Rather more than a year ago I publicly asked for a neat proof of a proposition that was useful in connection with viscous motion and the anchor ring. No replies were forthcoming, so ten months later I said I would publish my own solution. The essence of the proposition is in some of Gauss's work. The proof has now been published in the *Jour. Lond. Math. Soc.*, January 1932. It may disarm subsequent criticism if I add that an Indian has indirectly communicated to me a prior claim to having solved the problem of the anchor ring in visco. I am not familiar with his work, but as I made no claim to priority, he is welcome to any claim he can establish.

In my last article I made brief mention of a paper on Oberbeck's vortices by two Indians, Banerje and Barave. My comments were very restrained, but sufficiently pointed to show that mathematically the work was not to be taken too seriously. In the *Phil. Mag.*, **81**, the blue bonnets came over the border in fighting formation. Twa Scotsmen, Rutherford and Caldwell, " came from the hills where their hirsels were grazing " and, taking the paper *au grand sérieux*, made hay of it.

Heat and Moisture Conduction.—Much of the mathematical analysis that applies to one branch of study is so closely allied to other branches that separation is effected by mere terminology. We may here therefore fittingly take note of a number of papers, beginning with *Phil. Mag.*, **78**, " On Some Problems in the Conduction of Heat," by G. Green. This is apparently the fourth of a series published during the last four years. Ostensibly it gives " an entirely general method of investigating the solution of all problems involving the transmission of an effect by wave motion throughout a limited medium." That sounds very attractive ; but no claim is made that the method is more powerful than the orthodox methods. Perhaps this is as well, for some of the illustrative problems can be solved more neatly by a change to more suitable co-ordinates. This is noticeably the case in equation (30). " In all branches of physics involving wave motion," says the author, " it is always possible to find a solution to represent a periodic disturbance throughout an infinitely extended medium emanating from a definite source." I long to believe it ; unfortunately I know it to be untrue, and many an aspirant has been reluctantly compelled to dump his research into the waste-paper basket for this very reason.

One thing the paper teaches, and that is how not to do it. There occurs, not once but many times, the most needless and unsightly infraction of good mathematical writing that could well be imagined; a fraction, not even written in solidus form, with a square root sign and a vinculum. What a time the poor compositor must have had with it, especially that vinculum; and why, seeing that it was to be used so often, could it not have been replaced by a single letter!

In striking contrast, the same issue contains a paper by F. H. Schofield on the "Heat Loss from a Cylinder imbedded in an Insulating Wall." This is a twenty-page paper bearing all those marks of good workmanship that one is accustomed to associate with papers emanating from the N.P.L.; perhaps not very inspired, but a good honest attempt to master a difficult problem in the best manner short of the elegance that comes with exactitude. There is an adequate number of well-drawn diagrams; the paper is divided into suitably headed sections and prefaced by an abstract. The problem is treated as heat, but the author realises that, with a mere change of terminology, it solves kindred problems in allied branches of science. No extravagant claims are made for it, and there is the recognition that many practical problems are not wholly covered.

The outer rectangular boundary of the wall is taken as an isothermal. An imaginary inner boundary is also taken as an isothermal, of such shape and size that one of the isothermals comes pretty close to coincidence with the boundary of the cylinder. The application of the Schwarz-Christoffel method then produces a transformation in terms of Jacobian elliptic functions. The paper is amplified by one section on the graphical estimation of heat flow, and another on the electrical determination of the shape factor. The whole is nicely rounded off by a section dealing with an alternative method of theoretical treatment (incidentally not the only one); inexperienced writers of papers on applied topics might well take this paper for a model.

The cooling problem may be stated in more general terms. A quantity of one material is heated and placed between two masses of a different material, as a casting in its mould. Given the initial temperatures of the three regions and the temperatures at the two outer boundaries, it is required to find the subsequent temperature at any point. A general discussion from the viewpoint of integral equations will be found in a paper by W. M. Rust, *Amer. Jour. Math.*, 1932, vol. LIV, p. 1. A simple case, involving only one co-ordinate, is first treated. The case of semi-infinite outer regions has already been treated by Sommerfeld, *Math. Ann.*, 1894, **45**, the Green's function being

constructed by the method of images. The more general case leads to a system of Volterra integral equations of the second kind with bounded kernels. These latter vanish exponentially, so that the necessarily convergent successive approximations converge rapidly.

MATHEMATICAL PHYSICS.[1] By G. TEMPLE, Ph.D., D.Sc., Assistant Professor of Mathematics at the Imperial College of Science and Technology.

DURING the past year a most important advance in the classical theory of statistical mechanics has resulted from the application of the theory of linear transformations in Hilbert space. The main result obtained is a rigorous proof of the "ergodic theorem" or the hypothesis of "quasi-continuity of path." This result takes the form of a precise statement of the conditions for the existence of a "time average" for a single dynamical system and for its equivalence to an average over the phase space of an assembly of similar systems.[2]

Linear Transformations in Hilbert Space.—An admirable summary of the purely mathematical apparatus required has been given by M. H. Stone in three articles on the geometrical, analytical, and operational aspects of the theory of linear transformations in an abstract Hilbert space (see references at end). The special Hilbert space of the investigations summarised below is defined as follows :

Let P be a point of a region Ω in an N-dimensional phase space. The Hilbert space $\mathfrak{H}$ is the class of all complex, measurable functions $f(P)$ with a finite Lebesgue integral :

$$\int_{\Omega} |f|^2 \, d\omega,$$

$d\omega$ being an element of Ω. These functions are the "points" or "vectors" of $\mathfrak{H}$. The scalar product of any two vectors $f(P)$ and $g(P)$ is defined as

$$(f, g) = \int_{\Omega} f\bar{g} \, d\omega,$$

where $\bar{g}$ denotes the complex conjugate of g. The length of f is defined as

$$\|f\| = \sqrt{(f, f)}.$$

In the physical applications of this theory to an assembly of systems, the significant properties of the assembly are those

[1] The recent advances in Quantum Theory will be dealt with in a separate article.

[2] R. H. Fowler, *Statistical Mechanics*, Cambridge University Press, 1929, pp. 7–13.

which are valid almost everywhere in the phase space, *i.e.* with the exception of a set of points of measure zero. Accordingly the two important types of convergence of sequences of vectors,

$$f_1(\mathrm{P}), f_2(\mathrm{P}), \ldots,$$

are (*a*) "strong convergence," characterised by the condition that—

$$\| f_m - f_n \| \to 0 \quad \text{as} \quad m, n \to \infty;$$

and (*b*) "weak convergence," characterised by the condition that for any arbitrarily chosen vector $g(\mathrm{P})$,

$$(f_m - f_n, g) \to 0 \quad \text{as} \quad m, n \to \infty.$$

In case (*a*) there exists a limit vector $f(\mathrm{P})$ such that

$$\| f - f_n \| \to 0 \quad \text{as} \quad m \to \infty;$$

and in case (*b*) there exists a limit vector $f(\mathrm{P})$ such that

$$(f_n, g) \to (f, g) \quad \text{as} \quad n \to \infty \text{ for any } g\ (\mathrm{P}).$$

In both cases it is true that two limit vectors of the same sequence can differ only in a set of points of measure zero. These two types of convergence therefore provide the necessary freedom in the discussion of "normal" properties.

It remains to consider the linear transformations. A self-adjoint linear operator R in $\mathfrak{H}$ is a one-to-one punctual transformation of $\mathfrak{H}$ into itself such that

$$(\mathrm{R}f, g) = (f, \mathrm{R}g),$$

$$\text{and} \quad \mathrm{R}\,(\alpha f + \beta g) = \alpha \mathrm{R}f + \beta \mathrm{R}g,$$

where f and g are any vectors and α, β any complex numbers, Rf denoting the vector obtained by operating on f with R. Such transformations can be expressed in the canonical form

$$\mathrm{R} = \int_{-\infty}^{\infty} \lambda d\mathrm{E}(\lambda), \tag{1}$$

where the "spectral set of operators" $\mathrm{E}(\lambda)$ satisfy the conditions:

(*a*) $\mathrm{E}(\lambda)\,\mathrm{E}(\mu) = \mathrm{E}(\mu)\,\mathrm{E}(\lambda) = \mathrm{E}(\mu)$ if $\lambda > \mu$;
(*b*) $lim\ \mathrm{E}(\lambda) = 0$ if $\lambda \to -\infty$,
or 1 if $\lambda \to +\infty$;
(*c*) $\mathrm{E}(\lambda + 0) = \mathrm{E}(\lambda)$.

The discrete spectrum of R is the enumerable set of values of λ at which

$$\mathrm{E}(\lambda - 0) \neq \mathrm{E}(\lambda),$$

and the continuous spectrum is the set of intervals throughout which

$$E(\lambda) \neq E(\mu) \quad \text{if} \quad \lambda \gtrless \mu.$$

(These operational equations are, of course, equivalent to numerical relations, *e.g.* the canonical expression for R in (1) implies that

$$(Rf, g) = \int_{-\infty}^{\infty} \lambda d(E(\lambda)f, g) \,.)$$

The special linear transformations which play the leading rôle in the applications of this theory are the unitary transformations. A unitary operator U is a linear operator which leaves invariant all scalar products, *i.e.*

$$(Uf, Ug) = (f, g).$$

If a set of unitary operators U_s form a group, the parameter s can always be chosen so that

$$U_s U_t = U_{s+t}.$$

The infinitesimal operator of this group is

$$iR = [\partial U_s / \partial s]_{s=0}.$$

If $E(\lambda)$ is the spectral set of operators for R, the canonical expression for the group of unitary operators U_s is

$$U_s = \int_{-\infty}^{\infty} e^{i\lambda s} \, dE(\lambda). \qquad (2)$$

In the application of group theory to statistical mechanics the concept of transitivity is conveniently replaced by the more elastic idea of "metrical transitivity" (Birkhoff and Stone). A group is said to be metrically transitive if the only measurable and invariant vectors $f(P)$ are constant almost everywhere in Ω. An equivalent definition is that

$$m(A). \quad m(\Omega - A) = 0,$$

where A denotes any set of points in $\mathfrak{H}$ invariant under the group and $m(A)$ is the measure of the set A. A group is said to be "completely transitive" (Hopf, ref. 2) if each transformation of the group satisfies the condition for metrical transitivity.

Application to Assemblies of Hamiltonian Systems.—The application of the preceding theory to statistical mechanics depends upon the representation of the motions of a dynamical system by a group of unitary transformations in a Hilbert space. This simple and fertile idea is due to B. O. Koopman. It provides a powerful method of attacking the ergodic theorem and related problems of statistics and probability.

If q_k, p_k $(k = 1, 2, \ldots)$ are the values of the co-ordinates and the momenta of a Hamiltonian system at time t, the point

P_t in the phase space with co-ordinates $(q_1, q_2, \ldots, p_1, p_2, \ldots)$ represents the state of the system at this instant. The motion of this point gives rise to a group of transformations S_t defined by the equation

$$S_t P_o = P_t.$$

These transformations are the familiar contact transformations of general dynamical theory. Now this group of transformations S_t in the phase space induces a group of transformations U_t in the associated Hilbert space $\mathfrak{H}$,[1] defined by the equations

$$U_t f(P_o) = f(S_t P_o) = f(P_t).$$

These transformations are clearly linear ; since

$$U_s U_t = U_{s+t}$$

they have the group property ; and, since the element of the phase space $d\omega$ is invariant under the group S_t, the transformations U_t are unitary. The isomorphism between the groups S_t and U_t is the fundamental idea in Koopman's method as applied by v. Neumann and Hopf to the ergodic theorem.

This relation between the equations of motion and the unitary group U_t throws light upon the representation of q_k and p_k by trigonometric sums and integrals. The canonical expression for the unitary operators (2) shows that a representation by trigonometric series can only be valid in the exceptional case when the entire spectrum of U_t is discrete. In the general case both a series and an integral are required, and the representation is valid only in the sense of "strong convergence."

Koopman's method can also be employed to discuss Poincaré's problem of the mixture of liquids (Hopf, ref. 2). A steady flow of an incompressible fluid gives rise to a transformation group S_t. If initially a certain part of the fluid is red-coloured, we may enquire if the red colour becomes uniformly distributed, in general, after a long time. It is difficult to prove that the density of red-coloured liquid actually converges, or even weakly converges, with increasing time to the value for a uniform mixture. Hopf has shown that a necessary condition for this result is that the group S_t should be completely transitive.

The Time Average.—The time average of a function $f(P_t)$ characterising the state of a dynamical system at time t is determined by the values of the expression,

$$f_T(P_a) = \frac{1}{T}\int_a^{a+T} f(P_t)\,dt.$$

[1] The region Ω may be taken to be the whole of the phase space or those manifolds in the phase space which are determined by specifying the value of the energy or other constants of the motion.

v. Neumann and Hopf have given independent proofs that, as $T \to \infty$, the vectors $f_T(P_a)$ converge strongly to a limit $f^*(P_a)$ which is independent of a, *i.e.* which can vary only with the particular trajectory studied. Birkhoff (ref. 2) and Hopf (ref. 1) have obtained the less important but more precise result that the functions $f_T(P_a)$ actually converge to a limit $f^*(P_a)$, independent of a, everywhere except in a set of points of measure zero.

v. Neumann's proof depends upon the expression of U_t in canonical form (2). Hopf proves directly that

$$\| f_T(P_a) - f_{T'}(P_{a'}) \| \to 0 \quad \text{as} \quad T, T' \to \infty,$$

independently of a, a'. The strong convergence of the sequence $f_T(P_a)$ then follows from Riesz's theorem. Birkhoff's proof, in its original formulation, considered the successive intersections of a trajectory with a fixed manifold of section. Hopf has generalised this method by considering the sequence of points

$$P, \; P_1 = S_1P, \; P_2 = S_1P_1, \; . \; . \; . \; ,$$

obtained by the iteration of the operation S_1 on the initial point P.

If $$\phi_n(P) = [g(P) + g(P_1) + \; . \; . \; . + g(P_{n-1})]/n,$$

the limit, $$\lim_{n \to \infty} \phi_n(P),$$

exists almost everywhere in Ω. Hence, if

$$g(P) = \int_0^1 f(P_t)\, dt,$$

the time average,

$$f^*(P) = \lim_{n \to \infty} \frac{1}{n}\int_0^n f(P_t)\, dt,$$

exists everywhere in Ω apart from a set of points of measure zero.

The importance of this result for statistical mechanics is that it determines the significance of the " long-time averages " whose very existence had hitherto been a pious hope. For, if $f(P_t) = 1$ when P_t belongs to a set of points A, and $f(P_t) = 0$ for all other points, then the preceding argument shows that the time average $f^*(P)$ exists as a definite limit for almost all initial points P. The time average so defined represents the probability that the representative point should lie in A at any specified epoch.

The proof of the existence of this probability function $f^*(P)$ constitutes the first part of the ergodic theorem. The second part expresses this probability as the ratio of the volumes of A and Ω.

The Average over the Phase Space.—The second part of the ergodic theorem depends upon the following results (3) and (4). Since

$$U_s U_t = U_{s+t},$$

it follows that

$$U_s f_T(P_0) = f_T(P_s),$$

whence

$$U_s f^*(P) = f^*(P), \tag{3}$$

i.e. $f^*(P)$ is invariant under the group U_s. If $g(P)$ is any other invariant vector,

$$(f_T, g) = (f, g),$$

whence

$$(f^*, g) = (f, g). \tag{4}$$

If the group U_t is metrically transitive, the only invariants are "constant" functions; *i.e.* the time average $f^*(P)$ is independent of P except for a set of points of measure zero. $g(P)$ must also be a constant, and on writing $g(P) = 1$ in (4), it follows that

$$f^*(P) = \int_\Omega f(P)\,d\omega \Big/ \int_\Omega d\omega.$$

Hence the time average of $f(P)$ taken along any trajectory is equal to its average taken throughout the region Ω of the phase space. It follows that the probability that the representative point P on any trajectory should lie in a region A is "normally" equal to the ratio of the volumes of A and Ω.

It is clear that the metrical transitivity of U_t is a sufficient condition for the truth of the second part of the ergodic theorem, (Hopf, ref. 1). v. Neumann has proved that this condition is also necessary. This result completes the general discussion of the ergodic theorem. There only remains the special (and difficult) problem of verifying the metrical transitivity of U_t for particular Hamiltonian systems.

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ASTRONOMY. By R. W. Wrigley, M.A., Royal Observatory, Edinburgh.

The Deflection of Light in the Sun's Gravitational Field.—Various results of the Potsdam expedition to Sumatra for the eclipse of May 9, 1929, are published in *Zeitschrift für Astrophysik*, 1931, Band 3, Heft 3. One of the investigations was an attempt to check the Einstein effect, and no effort was spared to obtain an independent determination of the scale of the photographs and to avoid any distortion or other optical defect. The instrument was a double camera of 28-ft. focus used in conjunction with a coelostat, four exposures being made of the eclipsed sun and neighbouring stars, together with simultaneous photographs of a check field 25° away, and the same regions were again photographed six months later. A réseau was imprinted on all the plates so that any scale differences or distortion would be readily perceived during their measurement, and it was recognised that special precautions were necessary owing to the lack of symmetry in the distribution of the stars, nearly all of the eighteen used being on the same side of the sun. The mean of the measures of the four eclipse plates shows a definite deflection of the light in the sun's neighbourhood, but when the deflections are fitted to a hyperbolic curve and extrapolated to the sun's radius, the resulting value is surprisingly large, and instead of the 1″·75 predicted by the Relativity Theory it amounts to 2″·24 ± 0″·10. The earlier expeditions which had carried out this test were those from Greenwich in 1919, and from Lick in 1922. In the case of the former the original published value of 1″·98 has been increased to 2″·16 by taking account of the effect of the second order terms of refraction and aberration. Prof. Freundlich shows that the Lick result of 2″·05 would also be increased if a systematic error, introduced by using the outer ring of stars in the eclipse field to determine the scale, were eliminated. The revised value is 2″·27. Using the results of the three expeditions, the mean deflection is about 2″·2, which, while certainly not Newton's, is distinctly greater than Einstein's theoretical value. This result, backed by the apparent agreement of the three independent determinations, is very remarkable, but further eclipse observations will be necessary to convince the theorists who acclaim 1″·75 as the only possible value. If the higher value be proved correct, then some modification in the theory will be needed. The most ardent advocates of Einstein's general theory hardly regard it as absolute and final, though its importance is unquestioned. Prof. Freundlich also obtained photographs with an astrographic telescope, but at the time of writing these results have not been published. They will be of the greatest interest in spite of their smaller scale, the focal

length of the instrument being only 11 feet. It is unfortunate that the coming North American eclipse of August 31 will not give an opportunity for a further test. The maximum duration of the total phase will be only 104 seconds, and the sun will be situated in a field of comparatively faint stars.

Prof. Freundlich's eclipse plates have been examined by H. von Kluber for the presence of an intra-Mercurial planet, but without success. A body as bright as magnitude 9·5 at a distance exceeding 40′ from the sun's limb, or of magnitude 7 within that distance, would not have escaped detection, and there now seems but little chance of the existence of a planet of appreciable size within Mercury's orbit.

The Sun's Equatorial Rotation Velocity.—In Monthly Notices, *R.A.S.*, **92**, No. 2, J. Evershed submits evidence for an increase since 1928 in the solar rotation at the Equator as determined from spectrographic measures. All the earlier measures made between 1900 and 1911, including the visual ones of Dunér and Halm and the first photographic determinations at Mount Wilson and at Edinburgh all gave a value exceeding 2 km. per sec., which agreed closely with that derived from sunspot observations. A later series of measures made at Mount Wilson by St. John gave a smaller velocity of 1·90 km. per sec., which remained approximately constant till 1928. In 1929 and 1930 there was a tendency to increase, the value being 1·95. Evershed's latest observations, made between July and December 1931, give a mean velocity of 2·015 ± ·026, which is in good agreement with the measures of 1900–11, and, incidentally, with the sunspots. There is thus an indication of a possible variation with a period of some thirty years, which seems to be too long to permit a correlation with the changing polarity of sunspots. Evershed's measures were based on 15 to 20 iron lines situated either in the H and K region or between wave-lengths 4,000 and 4,100, and precautions were taken that no instrumental shift affected the deduced values for the rotation. The variations in velocity relate only to the gases outside the photosphere, the latter being apparently unaffected by movements in the reversing layer. It has been found by Adams and confirmed by Evershed that certain lines representing high levels in the reversing layer give larger rotation values than low-level lines. It therefore seems probable that the observed variation in the velocity of rotation is due to a recent rise in the level of absorption of the lines measured, and is related to changes going on in the reversing layer.

The Distribution of Stars in Space.—Several papers on this subject have lately been published by F. H. Seares. In the *Astrophysical Journal*, vol. LXXIV, No. 2, he considers the effect of absorption of light in space on the apparent distribution of

the stars when stated as a function of distance, and shows how the true space density can be expressed in terms of the absorption function and the apparent stellar distribution derived from star counts. To obtain the true distribution it is therefore necessary to make some assumption regarding the absorption coefficient, for at present definite knowledge both as to its amount and possible selectivity is lacking. Seares assumes various different values and calculates from his formulæ the corresponding stellar distributions. Taking Trumpler's value of 0·67 magnitude per 1,000 parsecs assumed constant throughout space (*Lick Bulletin*, 420), it is found that there is the expected increase in stellar density with distance in the galactic plane, but that the results obtained in other directions in space are anomalous, and indicate the probability of a variation of the absorption with both longitude and distance. Trumpler's value of 0·8 magnitude per 1,000 parsecs, which he found from his study of the diameters of galactic clusters, increases the difficulty of a theoretical increase in star density in inadmissible directions. Seares concludes that there must be large irregularities in the distribution of absorbing material; that this material is finely divided dust and not the molecules of a continuous stratum of gas; and that possibly it tends to concentrate about the galactic clusters.

In the *Astrophysical Journal*, vol. LXXIV, Nos. 4 and 5, Seares develops and illustrates a numerical method for determining the space-density function, in which the unknowns are the relative densities in successive spherical shells whose thicknesses correspond to a constant increment in the logarithm of the distance. The star counts given in Groningen Publication No. 27 for latitude 0° are used for a numerical illustration, and it is found that, if a constant luminosity function is adopted, there are indications of a rapid change in space density for stars in the neighbourhood of the sun. This result is not accepted owing to its contradiction by other evidence, and Seares concludes that the decrease in frequency corresponding to increasing distance from the sun, holds good only for the intrinsically brightest stars, while also the luminosity function changes with galactic latitude. Both these conclusions are in harmony with our present knowledge of the structure of the local system, the helium stars accounting for the excess of high luminosities near the sun.

A similar research has been carried out by Bart J. Bok, and is described in *Harvard Observatory Circular*, No. 371. He also has preferred a numerical method to an elaborate mathematical analysis, and considers that it gives reliable results for a galactic system consisting of separate star clouds. A very interesting comparison is made between the general luminosity

curve in the neighbourhood of our sun and the mean curve for the Magellanic Clouds. In the latter, all the stars are at practically the same distance from us, and their apparent magnitudes give a direct measure of their absolute magnitudes. A discussion of star counts in an external system may therefore be more simple and direct than the same problem in our own neighbourhood, and may be of great help in its solution. In the near future the star counts for the Magellanic Clouds will reach down to the twentieth magnitude, and then not only the shape of the general luminosity function but also the probable deviations from the mean curve will be determined. This will represent a great advance on our present knowledge of our own system. Following his analysis of star counts in low galactic latitudes, Bok finds evidence for the existence of a local cluster and a real density gradient near the sun, and he prefers this hypothesis to that of a variable absorbing cloud with a strong central condensation in our vicinity. He agrees with Seares in considering Trumpler's value for the coefficient of absorption to be too high, and favours an estimate of 0·40 magnitude per 1,000 parsecs remaining uniform throughout the galactic system. With this assumption, an analysis of the star counts of Groningen Publication, No. 43, confirms the existence of a local cluster, somewhat elongated in shape.

Stellar Stability.—In Publication No. 2 of the University Observatory, Oslo (1932), S. Rosseland deals with the theory of oscillating fluid globes, and extends the work of Lord Kelvin on the homogeneous liquid globe to include the cases of heterogeneous incompressible liquids and of gases with and without adiabatic changes of state. Following a mathematical treatment which reduces both problems to the solution of ordinary linear differential equations, the influence of dissipative agencies on the oscillation is studied, and a formula for the coefficient of stability is derived. This is then applied to the problem of a star built up on the standard model, which generates energy at a rate proportional to its mass. Such stars are found to be always stable whatever be their masses, and this result agrees with an earlier one reached by Eddington by an entirely different method. Rosseland here corrects certain of his results published in an earlier paper (Oslo Observatory, No. 1), and he also joins issue with Jeans regarding his theory of stellar stability and his hypothesis that stars are largely in a liquid state.

The Velocities of the Spiral Nebulæ.—In a letter to *Nature*, January 16, 1932, W. D. MacMillan expresses his scepticism regarding the interpretation of the shift towards the red in the spectral lines as a Doppler effect pure and simple, and offers an alternative explanation in terms of light quanta or photons.

If it be supposed that there is a small leakage of energy from the photon in its long journey of millions of years, due either to its inherent instability or to collisions with other photons, the frequency will decline with the energy and the spectrum lines will be shifted towards the red. It is suggested that, instead of a linear relation between the distance and the velocity of recession, the connection should be expressed by the equation

$$\frac{v}{c} = (1 - e^{-\beta x})$$

where v is the observed velocity, c that of light, x the distance, and β a constant. These two hypotheses are indistinguishable on the basis of the observational data, and the relation between frequency and distance due to Doppler effect,

$$\nu = \nu_0\left(1 - \frac{v}{c}\right) \text{ then becomes } \nu = \nu_0 e^{-\beta x} \quad . \quad . \quad . \quad (1)$$

If the percentage loss of energy ϵ from the photon per unit distance of travel is constant, then

$$\frac{1}{\epsilon}\frac{d\epsilon}{dx} = -\alpha,$$

where α is some constant, and consequently $\epsilon = \epsilon_0 e^{-}$

Dividing by Planck's constant h where $\epsilon = h\nu$, the frequency $\nu = \nu_0 e^{-\alpha x}$, which is indistinguishable in form from (1) above, and therefore from the law of Doppler effect derived from the observations of Hubble and Humason. The necessary rate of loss of energy in the light quantum is only 1 per cent. in a journey of 5,400,000 parsecs or 17,600,000 years.

An alternative explanation is put forward by M. E. J. Gheury de Bray in *Astronomische Nachrichten* No. 5844, and is based on Van Maanen's measurements of proper motion in his photographs of the spiral nebula M. 81. These showed that the star condensations, in addition to a rotational motion, were receding from the centre of the nebula with a velocity apparently roughly proportional to the distance therefrom. De Bray suggests that this spiral nebula provides a model on which the whole visible universe is built. Just as the satellite family of Jupiter represents in miniature the structure of the more comprehensive Solar System, so M. 81 is imagined as the model for a universe of similar spiral nebulæ, the individual components all being possessed of velocities away from the centre proportional to their distances, and the whole structure resembling, not an expanding soap bubble, but a rotating Catherine wheel. Needless to say, such a general rotational movement of the

whole system of spiral nebulæ can only be confirmed by a much longer period of observation than is now available, but the suggestion, taken merely as a suggestion, is interesting.

Astronomical Motion Pictures.—The educational value of moving pictures of celestial phenomena is now becoming more widely realised, and, as might have been expected, America is leading the way in the development of an instrument and a technique for their production. The University of Michigan has established at Lake Angelus, near Pontiac, a branch known as the McMath-Hulbert Observatory, devoted entirely to research in this field, and in the *Publications of the Observatory of Michigan*, vol. IV, No. 4, a description is given of the instrument employed and its special adaptations. The programme includes motion pictures of sunrise and sunset on the moon, the phases of Venus, the rotation of Jupiter and the movements of its satellites, stellar occultations, variable star cycles, motions of sun-spots, the activities of solar prominences, and cometary changes and movements. It is obvious that highly flexible drive-rate mechanisms are essential for the successful photography of bodies of such widely differing brightness and velocity, while it is also necessary to allow for the effect of refraction and parallax at considerable hour angles. The chief interest of this paper lies in the description of the electrical controls and other devices directed to these ends. The McMath-Hulbert Telechron driving clock depends for its accuracy on the close regulation by the Detroit-Edison Co. of the cycle output, and the control of the motor speed is secured by a frequency changer, which alters the number of cycles of the current either up or down. The speed of drive of the film can be varied within very wide limits by sets of change gear, easily removed from or replaced on their appropriate shafts, and a partial gear, from which a calculated number of teeth have been removed, enables a suitable relation of dark time to light time to be adopted. Lunar photography has necessitated a special declination drive, consisting of a set of compound change gears driven by a synchronous motor, and it is also possible to allow for variations in the moon's refraction and parallax in both co-ordinates. Tables are given for their convenient calculation for different hour angles.

PHYSICS.

By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London.

American Contributions.—We must first consider a few important papers on the photo-electric and thermo-electric properties of metals. We turn first to an experimental study of the photo-electric and thermo-electric properties of palladium by Du Bridge and Roehr (*Phys. Rev.*, **39**, 99, 1932). This

material was chosen for investigation because of the relation which is known to exist between the position of an element in the periodic system and the energy necessary to remove an electron from its surface, *i.e.* its photo-electric work function. Whilst the alkali metals possess very low work functions, there is a tendency towards high values at the end of each period. Thus, platinum, the last element of the third long period, has a value of 6·3 volts, the highest so far recorded.

Hence it was desired to know the values in the cases of palladium and nickel, which are the last elements in the two preceding periods, to see if they, too, were high. The authors find that the value for palladium is $4{\cdot}99 \pm 0{\cdot}04$ volts, a value which, although lower than that of platinum, is certainly higher than that recorded for any other element in the period to which the former belongs. Glasoe (*Phys. Rev.*, **38**, 1490, 1931) has shown that a similar statement holds for nickel.

Du Bridge and Roehr used a pyrex tube in which a strip of palladium foil was mounted along the axis of three concentric nickel cylinders. Of the latter, the two outer cylinders were earthed and acted as guard rings. The innermost cylinder was connected to a Compton electrometer through an insulating seal in the side of the tube.

Mono-chromatic light from an air-cooled, quartz mercury arc entered the tube through a quartz window, and passed through a hole in the cylinder on to the filament during the photo-electric measurements. Or, the light from the filament itself could be examined through the window, by means of an optical pyrometer of the disappearing-filament type, when it was desired to know the temperature of the filament. The inner surface of the quartz window was protected from the deposition of metal by means of a magnetically operated shutter.

In making thermionic measurements, simultaneous readings of the thermionic current and filament temperature were taken. The electrometer was here used as a null instrument in conjunction with a potentiometer. The thermionic current was found to be given by the expression $A{\cdot}T^2 e^{-b/T}$, where b was equal to 57,950°K, which corresponds to a thermionic work function of 4·99 volts. The value of the constant A, which could not be accurately determined, was as close to the theoretical value, 60 amp/deg.^{2} cm.^{2}, as could be expected. This is in contrast to the very high value for platinum, but is in agreement with the suggestion that high values of A are only obtained with very high values of b.

The photo-electric currents were measured with temperature for six different wave-lengths, and the photo-electric current was plotted against the wave-length for three different temperatures. From the latter curves it seemed that the photo-

electric threshold appeared to shift from $\lambda = 2{,}490$ to $2{,}660$ Å—*i.e.* from a work function of 4·95 to 4·64 volts—for a change of temperature from 305° to 1,078° K. As we shall soon see, this apparent shift is illusory.

Now, it is particularly fortunate that R. H. Fowler (*Phys. Rev.*, **38**, 45, 1931) has recently given a theory of photo-electric emission with which Du Bridge has compared the above experimental results. In Fowler's theory it is assumed that the electrons within a metal obey the Fermi-Dirac statistics, and that the number ejected by the absorption of unit amount of energy of light of any frequency ν is proportional to the number of electrons within the metal which have energies normal to the surface sufficiently great to overcome the surface potential step when augmented by the energy $h.\nu$. For the sake of mathematical simplicity, Fowler treats only the case where ν is close to the threshold frequency, ν_0, a restriction which is also imposed upon the experimenter by the difficulty of handling light of high frequency.

Fowler thus obtains for the photo-electric current I the following expression

$$log\ \mathrm{I}/\mathrm{T}^2 = \mathrm{B} + \Phi(\mu),$$

where B is a constant independent of ν and T, $\mu = h(\nu - \nu_0)/k{\cdot}\mathrm{T}$, and $\Phi(\mu)$ is a universal function of μ which we need not reproduce here.

It therefore follows that ν_0 may be obtained for a given surface by plotting log I/T^2 against $h{\cdot}\nu/k{\cdot}\mathrm{T}$, when the horizontal displacement required to make the experimental curve coincide with the theoretical curve is equal to $h{\cdot}\nu_0/k{\cdot}\mathrm{T}$. Fowler showed this to be correct with the experimental data for silver, obtained by Wrinch (*Phys. Rev.*, **37**, 1269, 1931); for gold, obtained by Morris (*Phys. Rev.*, **37**, 1263, 1931); and for tantalum, obtained by Cardwell (*cf. Phys. Rev.*, **38**, 45, 1931). Du Bridge and Roehr now show that this procedure is correct in the case of palladium, the work function thus obtained being $4{\cdot}97 \pm 0{\cdot}01$ volts, whereas the value obtained by extrapolation from the curve of photo-electric current against wave-length at 305°K, *i.e.* room temperature, gave 4·95. Hence, the agreement is as complete as one could reasonably expect. This means that the Fermi electron velocity distribution, on which Fowler's theory is based, receives very direct and convincing support.

Now, as Du Bridge takes pains to emphasise in a further paper (*Phys. Rev.*, **39**, 108, 1932), it is worth our while to examine a few of the most striking results of Fowler's theory. Firstly, since log $(\mathrm{I}/\mathrm{T}^2)$ is shown by experiment to be a universal function of μ, the analysis and comparison of experimental

results become greatly simplified—indeed, in a way which one could not possibly suspect from an examination of the experimental curves of photo-electric current with wave-length, alone.

Secondly, ν_0 is not the threshold frequency obtained by direct extrapolation from the latter curves. For Fowler's analysis shows that, at any temperature above 0°K, the photo-electric current does not fall to zero at $\nu = \nu_0$, but approaches zero asymptotically as ν decreases. Hence, there can be no sharply defined threshold frequency at any temperature above absolute zero. Since, however, the current is proportional to $(\nu - \nu_0)^2$ at absolute zero, ν_0 is a definite characteristic of the surface, and may be called the true threshold frequency, which may be obtained from measurements at ordinary temperatures. Hence ϕ_0, defined as $h{\cdot}\nu_0/e$, the work function, is also a true characteristic.

Thirdly, Fowler's theory predicts an increase of photo-electric current with temperature, the increase depending in a marked manner on the incident frequency. This is quite contrary to the earlier experiments, where photo-electric currents produced by unresolved light were practically independent of the temperature. However, more recent experiments have shown this increase to exist, Ives having shown that it is greater for light of longer wave-length.

The quantitative experiments of Wrinch, Morris, and Du Bridge and Roehr, to which we have referred above, are in complete agreement with Fowler's theory. For $\nu = \nu_0$, the current is proportional to T^2, but for higher frequencies the variation is much less rapid and is almost negligible for light whose wave-length is more than 200 Å on the short-wave side of the threshold. When ν is less than ν_0—there being no true threshold above absolute zero—the variation is extremely rapid. The temperature changes observed experimentally are completely explained by the increase in thermal energy of the electrons alone.

Fourthly, the last statement leads us to expect a lack of sharpness in the maximum velocity of the emitted photo-electrons at high temperatures. This lack of sharpness is, fortunately, not very apparent at room temperatures, and does not lead to serious errors in finding ν_0 by extrapolation, as we have just seen in the case of the experiments with palladium. It is, however, important at high temperatures, and we do not know its effect on the measurements of the maximum electron velocities at these temperatures.

Fifthly, as Du Bridge shows, we may plot the function $\Phi(\mu)$ as a function of log μ, when the curve consists of two branches, one for positive and the other for negative values of μ. Con-

sidering the positive branch, this means that if we plot the experimental values of log (I/T^2) against log (I/T), *i.e.* $-\log T$, we must obtain a curve which, by an horizontal displacement parallel to itself, should coincide with the theoretical curve. The vertical shift, as in an earlier case above, does not interest us.

Now, the above-mentioned horizontal shift is equal to log $h(\nu - \nu_0)/k$, because $\mu = \log [h(\nu - \nu_0)/k] - \log T$. Hence, if we know ν, ν_0 is known. We note, in fact, that $h(\nu - \nu_0)/k$ is a kind of characteristic temperature for the particular surface and ν employed. The main importance of this method of plotting is that we can find ν_0 by measurements with one frequency only. Again, if a series of such isochromatic curves is obtained, no reduction of the curves to unit intensity is necessary, because the vertical shift does not concern us.

The new method of plotting was very satisfactory in the case of the experimental results with palladium and with Morris's results for gold. In both cases all the experimental points fell on a smooth curve. For palladium, ϕ_0 was found to be 4·97 volts, and for gold 4·81 volts.

Turning now to the negative branch of Du Bridge's theoretical curve, we realise that this branch refers to observations which are taken on the low-frequency side of the true threshold ν_0. Such observations are difficult to make, owing to the smallness of the currents and to the huge effect of stray light in this region. Du Bridge, however, managed to obtain a few such observations. Their agreement with the theoretical curve was within the limits of experimental error, and they gave a value of ν_0 within about 1 per cent. of the value otherwise obtained. They may therefore be taken as a further experimental verification of a theory which will do much to clarify our views on photo-electric and thermionic phenomena.

Some interesting discussions took place at the meeting of the American Physical Society at Schenectady last September. They are reproduced in the *Phys. Rev.*, **39**, 337, 1932. At least two contributions are worthy of special comment. The first is Cioffi's paper on hydrogenised iron which will be dealt with elsewhere in this number of Science Progress. The second is a description of some new experimental methods in ferromagnetism, by S. L. Quimby.

Quimby described the production of very pure nickel single crystals in the form of rods 4 to 6 mm. in diameter and 5 to 10 cm. long. With such rods he measured the thermal expansion in the neighbourhood of the ferromagnetic Curie point. He found results similar to those previously reported for polycrystalline nickel. It appears that the coefficient of thermal expansion of a nickel rod reaches a sharp maximum at about

300° C., then decreases sharply within the next 15° C. or so, and, finally, rises to a value in the immediate vicinity of the ferromagnetic Curie point which increases but slowly with further rise in temperature.

Quimby also investigated the variation of Young's modulus of single crystal rods of nickel by a very ingenious method. A rod was sawn in half; the sawn ends were ground flat and cemented to the opposite sides of a piezo-electric quartz plate, 0·4 mm. thick, by means of a special cement. The electric axis of the quartz was parallel to the axis of the rod. The two halves of the rod were connected by fine wires to an oscillating electric circuit, so that an alternating potential difference was established across the quartz. The latter therefore suffered alternating strains which were transferred to the nickel, the whole system thus being set into forced elastic vibration.

The current supplied to the small condenser, of which the quartz plate formed the dielectric, was measured. The whole system could be set into resonant vibration. In the neighbourhood of the resonant frequency, the current supplied to the small condenser exhibited the well-known successive maximum and minimum values as the frequency of the supply was increased to pass through the region of resonance. If the maximum and minimum currents and the frequencies at which they occurred were measured, it was possible to calculate the resonant frequency. Allowance was made for the free period of the quartz plate itself, so that the free period of the nickel rod was thus obtained. The latter period of course depended on the value of Young's modulus for the rod.

Quimby gives details of the method used to cement nickel to quartz, and of the method of measuring high frequencies with the great accuracy necessary. Young's modulus for these rods fell fairly quickly with temperature until about 200° C., when it then increased until the ferromagnetic Curie point was reached, after which it again decreased with rise in temperature.

A new determination of the ratio of the charge to the mass of an electron by means of the Zeeman effect is described by J. S. Campbell and W. V. Houston (*Phys. Rev.*, **39**, 601, 1932). This work was started before the cathode-ray determinations of Chaffee and Perry (*Phys. Rev.*, **36**, 904, 1930) and of Kirchner (*Phys. Zeit.*, **31**, 1074, 1930) were published.

It will be remembered that Birge suggested that the difference between the more accurate cathode-ray determinations, such as those of Wolf, and the spectroscopic determinations of Babcock was so great that the two sets of experiments were really measuring different quantities; *i.e.* that the ratio e/m for an electron in a discharge tube was not the same as that for a valency electron in an atom, even after the necessary allowance

had been made for the known variation of mass with velocity. The value from Wolf's experiments was $1{\cdot}768 \times 10^7$ e.m.u. per gm., whilst that found by Babcock was $1{\cdot}761 \times 10^7$.

The value found by Chaffee and Perry was in agreement with Babcock's value, and they indicated that the higher value found by Wolf was probably due to the presence of a very small amount of gas in his discharge tube. For the sake of completeness, it remained only to show that Babcock's spectroscopic determination was exact.

Campbell and Houston examined the Zeeman effect with the Cd 6439 line and the Zn 6362 line, for which lines the g-factors, or Landé splitting factors, are accurately known. These factors are actually very nearly equal to unity. With a specially cooled solenoid they produced a steady field of 7,300 gauss over a 6-cm. length in the middle of the solenoid, where the source of light was placed. The accurate calibration of the solenoid is very fully described in their paper.

The spectroscopic measurements were made with a Fabry and Perot interferometer, for the above lines are singlets, and the Zeeman doublets, obtained when the sources are viewed along the lines of force, are ideal for examination with this instrument. Appropriate corrections were made for the fact that the various components which go to make up each line of the Zeeman doublet do not overlap exactly, resulting in an unresolved but complex line, whose centre of gravity must be calculated from the known formulæ given in treatises on the theory of spectra lines. The value found for e/m was $1{\cdot}7579 \pm 0{\cdot}0025 \times 10^7$ e.m.u. per gm. This is a little lower than Babcock's value, but the accuracy is not sufficiently great for any significance to be attached to the difference.

A comprehensive survey of the production of extremely short electromagnetic waves by the method of Barkhausen and Kurz, is given by G. Potapenko (*Phys. Rev.*, **39**, 625, 1932). Barkhausen and Kurz placed a comparatively large positive potential between the grid and filament and between the grid and plate of a valve. Electrons were imagined somehow to pass through the grid, be repelled by the plate, to retrace their paths almost back to the filament, and so continue to oscillate backwards and forwards through the grid. The short waves generated, apparently by this strange behaviour of the electrons, were communicated to a Lecher wire system.

The arrangement used by Potapenko is very similar. Imagine two long parallel copper wires. Let one wire be cut at its mid-point. Join one of the cut pieces to the plate and the other to the grid of a valve. Cut the other wire at its mid-point and insert a "ballast" condenser—a condenser of capacity equal to that of the valve—between the two pieces. Bridge the two

distant ends of the parallel wires with movable-plate bridges. Connect the bridge coupled with the piece of wire joined to the plate through a choke coil to the filament. Connect the bridge coupled with the piece of wire joined to the grid through a choke coil to the positive pole of a battery. Couple a Lecher wire system loosely with the plate circuit, and short waves will be communicated to it.

Vacuum tubes may thus be made to generate two types of waves. Firstly, we have the Barkhausen and Kurz waves, whose period is almost equal to the time necessary for an electron to go from the filament to the plate and back again. Secondly, there are waves of shorter wave-length, called dwarf waves. These are waves produced by circuits within or without the valve, such that the electrons perform two or more complete journeys almost from the filament to the plate and back again during the time normally taken by an electron in making this journey. They are particularly important, as the higher orders are generated with lower grid potentials, *i.e.* under steady working conditions of the tube. Potapenko has devised an effective diagrammatic method of representing the various conditions of operation of the tube, *i.e.* the grid voltage and plate current as functions of the frequency of the short waves generated under these conditions.

Three new papers on cosmic radiation and allied problems have just appeared. In the first (*Phys. Rev.*, **39**, 391, 1932) R. A. Millikan records that, after eliminating the possibility of temperature disturbances in high-pressure electroscopes, the sun can be proved to have no direct influence on cosmic radiation intensities, at any rate within the limits of experimental error, which is of the order of one-third of 1 per cent.

In the second (*Phys. Rev.*, **39**, 397, 1932) Millikan deals with the lack of saturation in measurements with high-pressure electroscopes. Thus, the residual ionisation in an electroscope at very great, theoretically infinite, depths in water was found to be an inverse function of the pressure inside the electroscope. Moreover, when the pressure was increased from 1 to 30·1 atmospheres the ionisation current rose only 13·80-fold, both for cosmic radiation and for γ-rays, a point of some theoretical significance.

The third paper is a report of an attempt to deflect cosmic radiation by means of a magnetic field, carried out by L. M. Mott-Smith (*Phys. Rev.*, **39**, 403, 1932). Three Geiger-Müller counters were arranged in line, and were so connected by valve arrangements that a signal was made only when all three counters were simultaneously activated by the passage of a single cosmic ray through them. Between the second and third counters a block of magnetised iron, a part of

a closed-core electromagnet, was placed. The field inside the iron was about 17,000 gauss, and the iron was of such thickness that an observable deflection of the radiation should have resulted if the latter consisted either of electrons which had fallen through a potential difference of 2×10^9 volts or less, or of protons which had fallen through 10^9 volts or less. Such a deflection would have resulted in a decrease in the number of signals observed per hour when the magnet was excited. No decrease was observed when the magnet was excited, and we may conveniently consider the following statement, which is practically an extract from Mott-Smith's paper.

It seems difficult to believe that the radiations responsible for the signals were electrons or protons, unless the effective magnetic field in the iron was of a different order of magnitude from the value of the magnetic induction, a point which it would be desirable to test with an ordinary air magnetic field, for which, of course, powerful electromagnetic equipment would be required.

If the signals were caused by the passage of a photon through the counters, the above results would be at once explained. This, however, seems to be excluded both on theoretical and experimental grounds. For Bothe and Kolhörster have shown theoretically that photons cannot produce such signals. Again, Mott-Smith and Locher (*Phys. Rev.*, **38**, 1399, 1931) have shown that the radiation which produces such a signal also produces an ionisation track in a Wilson cloud chamber, which also indicates that the radiation is not a photon.

Another possible explanation is one which has been put forward by Pauli, and by Carlson and Oppenheimer (*Phys. Rev.*, **38**, 1787, 1931), namely, that the cosmic radiation is made up of neutrons, *i.e.* particles in which the positively and negatively charged constituents are so close together that they produce no detectable external field of force. Hence they would not be deflected by passage through a magnetic field. Carlson and Oppenheimer also calculate that a neutron might produce the amount of ionisation observed by Mott-Smith and Locher in a Wilson cloud chamber.

Mott-Smith concludes his paper with the statement that although the possibility of a neutron is in many ways attractive, it would seem that evidence of a more direct nature would have to be found for the existence of neutrons before it could seriously be concluded that cosmic radiation phenomena are due to them. In the next section we shall deal with the evidence of a more direct nature.

The Neutron.—The first direct evidence in favour of the existence of the neutron is to be found set forth in a letter from

J. Chadwick, published in *Nature* of February 27, 1932. That evidence was reviewed, with customary clarity and restraint, by Lord Rutherford in his lecture on the origin of γ-rays, given at the Royal Institution on March 18.

It had been found by several investigators that beryllium, when bombarded by α-rays from polonium, emitted a very penetrating radiation; in fact, so penetrating that it could pass through nearly an inch of lead before being reduced to one-half its initial intensity. This radiation was recently studied by M. Joliot and Mme Curie-Joliot (the son-in-law and daughter of Mme Curie), who allowed it to pass through a thin window into an ionisation chamber. They found that, instead of showing a slight decrease, the ionisation produced in the chamber was actually increased when a film of material containing hydrogen was placed between the beryllium target and the window. This effect was shown to be due to protons expelled from the film with velocities up to nearly 3×10^9 cm. per sec.

Now, the most effective way of dealing statistically with such protons is to examine them by means of a valve counter. This was done by Chadwick, who found that the radiation from beryllium ejected particles from hydrogen, helium, lithium, beryllium, carbon, air, and argon. He found, however, that whilst the particles ejected from hydrogen appeared to be swift protons, those ejected from the other elements appeared to be heavier recoil atoms, *i.e.* atoms which had experienced powerful collisions without suffering disruption.

Now, the most efficient method of examining recoil atoms is by means of the Wilson cloud chamber, and Chadwick and Feather carried out an investigation along these lines. They found that some of the recoil atoms of nitrogen produced at least 30,000 ions, and their range was sometimes as great as 3 mm. in air at N.T.P.

These facts are of great importance, for M. and Mme Joliot suggested that the radiation from beryllium took the form of photons with a quantum energy of 5×10^7 electron-volts. They further suggested that energy was imparted to a proton by a process similar to that which occurs in the Compton scattering of γ-rays. This would certainly explain the range of velocities observed with the ejected protons. It would, however, also predict that a nitrogen recoil atom could not travel more than 1·3 mm. in air at N.T.P., and that it could not produce more than 10,000 ions. These numbers are, however, much smaller than those found by Chadwick and Feather. To preserve the suggestion that the radiation from beryllium had a quantum character, it would be necessary to admit that energy and momentum cannot be conserved in these collisions.

Chadwick avoids this unpleasant admission, by showing that all the experimental results so far obtained can be explained on the assumption that the radiation from beryllium consists of particles of unit mass and zero charge; in other words, of neutrons. It is suggested that a Be^9 nucleus captures an α-particle, and that a C^{12} nucleus is thereby formed and a neutron expelled. Under these circumstances sufficient energy would be available to give the neutron a velocity of over 3×10^9 cm. per sec., and thus cause it to produce recoil atoms with the velocities found by experiment.

The importance of measuring in the Wilson chamber the recoil tracks of various atoms produced by the radiation from beryllium is now apparent. A comparison of such tracks should enable us to calculate the mass of the neutron. This was done by Chadwick, and a mass about the same as that of a hydrogen atom was found for the neutron. The experiments are, however, only in their early stages, for, clearly, the presence of the neutron is bound to open up a new field of research.

Finally, at a time when every available expansion chamber must be working "overtime" in the intensive search for neutrons, it is fitting that we should here record that on March 18 the Duddell Medal of the Physical Society of London was presented to Prof. C. T. R. Wilson, the inventor of the Wilson cloud chamber.

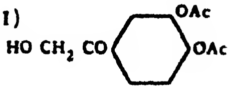
ORGANIC CHEMISTRY. By J. N. E. Day, M.Sc., A.I.C., University College, London.

Robinson and co-workers have recently published a further series of papers on the synthesis of anthocyanins (*J.C.S.*, 1931, 2665, 2672, 2701, 2715, 2722, 2730, 2732, 2738) (see this journal, **26**, 202). The preparation of 3-β-glucosidylcyanidin chloride (IV) has been carried out in the following way: the sodium salt of ω-3 : 4-trihydroxy-acetophenone with acetic anhydride gave ω-hydroxy-3 : 4-diacetoxyacetophenone (I); this, when treated with o-tetra-acetyl-α-glucosidyl bromide and silver carbonate gave ω-o-tetra-acetyl-β-glucosidoxy-3 : 4-diacetoxyacetophenone (II). Condensation with o-benzoyl-phloroglucinaldehyde gave (III), which on hydrolysis with sodium hydroxide and treating with hydrochloric acid gave the required compound (IV), which has been shown to be identical with chrysanthemin chloride from the flowers of the deep red chrysanthemum.

The preparation of pelargonidin 3-β-glucoside was referred to in a previous article (this journal, *ibid.*). The isomeric β-glucosides have now been prepared: o-benzoylphloroglucin-aldehyde and 4-tetra-acetyl-β-glucosidoxy-ω-acetoxyacetophe-none gave finally in the usual way pelargonidin chloride 4′-β-

glucoside (V); o-benzoylphloroglucinaldehyde was converted to 6-hydroxy-2 : 4-dibenzoyloxybenzaldehyde, the tetra-acetyl-glucoside was prepared, hydrolysed, and condensed with ω-4-dihydroxyacetophenone, giving pelargonidin 5-β-glucoside (VIII); o-benzoylphloroglucinaldehyde was converted into the tetra-acetyl-β-glucoside (VI), and this with ω-4-dihydroxyaceto-phenone gave pelargonidin chloride 7-β-glucoside (VII).

(I)



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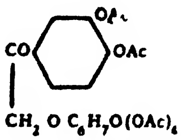

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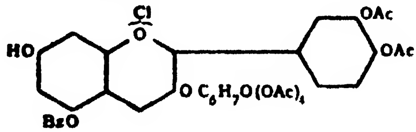

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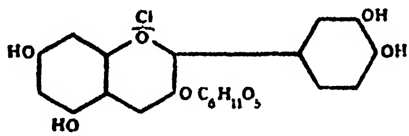

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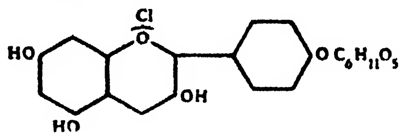
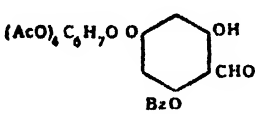


(VI)



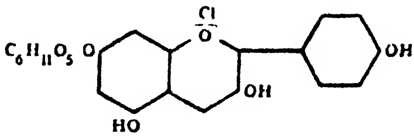
3-β-Glucosidyl-malvidin chloride (IX) has been synthesised from ω-o-tetra-acetyl-β-glucosidoxy-4-acetoxy-3 : 5-dimethoxy-acetophenone and o-benzoylphloroglucinaldehyde, and shown to be identical with œnin chloride, the pigment obtained from the skin of the purple-black grape.

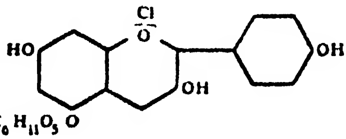
3-β-Glucosidylpeonidin chloride (X), prepared from ω-o-tetra-acetyl-β-glucosidoxy-4-acetoxy-3-methoxyacetophenone and o-benzoylphloroglucinaldehyde, has been shown to be identical with one of the pigments of American cranberries.

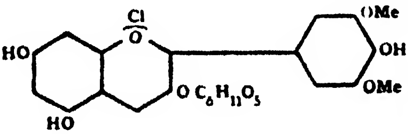
The syntheses of 3-β-galactosidylcyanidin chloride, 3-β-galactosidylpeonidin chloride, 3-β-glucosidylfisetinidin chloride,

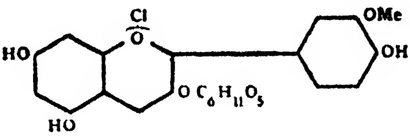
5-β-glucosidyl- and 5-lactosidyl-hirsutidin chlorides are also described.

Smiles and co-workers report an interesting rearrangement of certain sulphur compounds under the influence of alkali (*J.C.S.*, 1931, 914, 2207, 3264). Thus the *iso*-β-naphthol sulphide (XI) gives 2-naphthol-1-sulphide (XII), while the *iso*-sulphone (XIII) does not react. In the case of 2-naphthol-1-

(VII) 

(VIII) 

(IX) 

(X) 

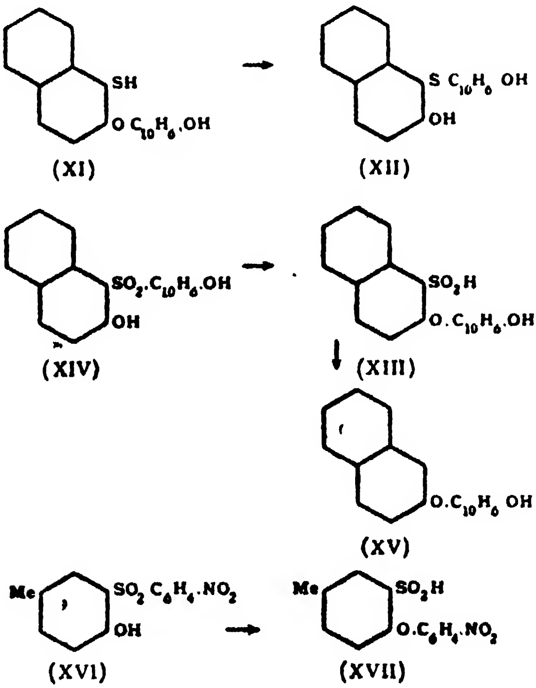
sulphone (XIV) the reaction takes place, but at the temperature of the experiment, in place of (XIII), the dinaphthyl oxide (XV) was isolated. A further example is given by 2-nitrophenyl-4-hydroxy-*m*-tolylsulphone (XVI), giving 2-nitrophenyl-3-sulphino-*p*-tolyl ether (XVII). These results are some of those discussed in the papers, mainly from the point of view of the charge on the sulphur atom.

Morgan and Coulson (*J.C.S.*, 1931, 2323), continuing their work on the methylated anthracenes (see this journal, **25**, 12), have now prepared 2 : 3 : 6 : 7-tetramethylanthracene and the corresponding quinone required for reference purposes in the identification of a tetramethylanthracene from the anthracene fraction of tar distillates.

2 : 4 : 5 : 3′ : 4′-Pentamethylbenzophenone (XVIII) was obtained by condensing 3 : 4-dimethylbenzoyl chloride (XIX) with ψ-cumene, in the presence of aluminium chloride. 3 : 4-Dimethylbenzoyl chloride, when treated with aluminium

chloride, gave 2 : 3 : 6 : 7-tetramethylanthraquinone (XX). 2 : 3 : 6 : 7-Tetramethyl-9-anthrone (XXI) was obtained by heating the above pentamethylbenzophenone (XVIII) ; oxidation of this with chromic anhydride gave the 2 : 3 : 6 : 7-tetramethylanthraquinone (XX), while reduction with sodium in amyl alcohol gave 2 : 3 : 6 : 7-tetramethyl-9 : 10-dihydroanthracene (XXII). 2 : 3 : 6 : 7-Tetramethylanthracene (XXIII) was obtained from the above compound (XXII) by heating with selenium.

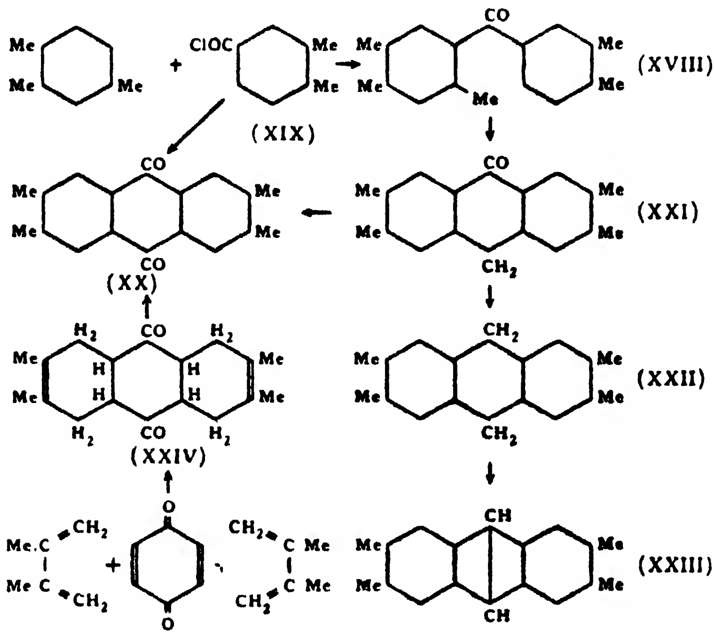
In order to show definitely the position of the four methyl groups in the tetramethylanthracene, the substance was also



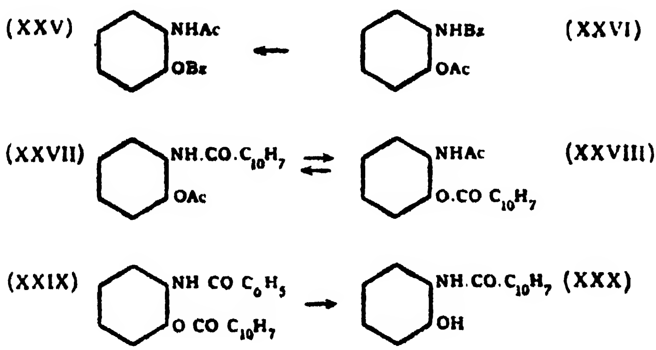
prepared in the following way : condensation of 2 : 3-dimethyl-$\Delta^{1:3}$-butadiene with *p*-benzoquinone gave 2 : 3 : 6 : 7-tetramethyl-$\Delta^{2:6}$-octahydroanthraquinone (XXIV). When this was treated with alcoholic potash it gave an isomeride which was converted, by means of oxygen, to 2 : 3 : 6 : 7-tetramethylanthraquinone (XX).

Further work on the migration of acyl groups in *o*-aminophenols is described by Bell (*J.C.S.*, 1931, 2962). 2-Acetamidophenyl benzoate (XXV) (prepared from 2-acetamidophenol and benzoyl chloride) was unchanged by heating above its melting-point (by boiling in xylene) ; on the other hand, 2-benzamido-

phenol acetate (XXVI) (prepared from 2-benzamidophenol and acetyl chloride), on heating to 150°, was partly converted to 2-acetamidophenyl benzoate. 2-α-Naphthamidophenyl acetate



(XXVII) on heating was partly converted to 2-acetamidophenyl α-naphthoate (XXVIII), and the latter compound (XXVIII) on heating was partly converted to the former (XXVII).



2-α-Naphthamidophenyl benzoate and 2-benzamidophenyl α-naphthoate (XXIX) were both unchanged by heating; on hydrolysis both gave 2-α-naphthamidophenol (XXX). These and other results are discussed in the paper.

BIOCHEMISTRY. By P. Eggleton, D.Sc., University, Edinburgh.

Glutathione.—A series of papers by E. C. Kendall, B. F. MacKenzie, and H. L. Mason, beginning in vol. 84 of the *Journal of Biological Chemistry* in 1929, has led to the identification of glutathione though not as yet to its synthesis. Starting out from the fact that glutathione was found to be a tripeptide of cystine, glutamic acid, and glycine, nine of the twelve possible arrangements of these three amino acids were eliminated by a consideration of the action of hypobromite on the molecule. The surviving three were glycyl-glutamyl-cysteine, glutamyl-cysteinyl-glycine, and glutamyl-glycyl-cysteine. Formation of glycyl-cysteine anhydride on hydrolysis in boiling water removes the first of these possibilities (*J. Biol. Chem.*, 1930, **87**, 55–79). The glutamyl-glycyl-cysteine possibility was eliminated by the fact that when the ester of glutathione (prepared by treatment with hydrochloric acid gas in absolute alcohol) was treated with phenyl magnesium bromide, the addition product (with an N : S ratio of 3 : 1) gave diphenyl amino ethyl alcohol on hydrolysis, showing that the carboxyl group of glycine in glutathione is not substituted (*J. Biol. Chem.*, 1930, **88**, 409–23). Further study of the hydrolysis products of glutathione reported in the same paper all confirmed the view that the molecular arrangement is that of glutamyl-cysteinyl-glycine. Hydrolysis of crystalline glutathione in water at 62° gives a large yield (approximately two-thirds theoretical) of pyrrolidone carboxylic acid. This acid does not appear to be formed via free glutamic acid, for the latter was found to be quite stable in the presence of glutathione at this temperature. There was little or no corresponding anhydride formation on the part of the cysteinyl-glycine simultaneously formed. Some measurements were made of the hydrolysis of glutathione by erepsin. The unusual slowness of this hydrolysis led Mason to the conclusion that the erepsin does not catalyse the primary hydrolysis given above, but that it accelerates the hydrolysis of cysteinyl-glycine. There was no evidence of the production of diglutamyl-cystine, contrary to the experience of Grassman, Dyckerhoff and Eibeler with pancreatic carboxy-polypeptidases (*Zeit. f. Physiol. Chem.*, 1930, **189**, 112–20).

Oxidised glutathione has been prepared recently by Mason (*J. Biol. Chem.*, 1931, **90**, 409–16) by aerating an alkaline glutathione solution containing a trace of ferric sulphate. As had been found by Hopkins, the product shows a deficiency of sulphur. Oxidation with ferricyanide gave the same result, but Mason has produced evidence that this is not due to decomposition but to the formation of a compound of the oxidised glutathione with the alcohol used for recrystallisation. Electrometric titration revealed two acid groups to each amino

group and an equivalent weight of 180 (theoretical for GS—SG.$2C_2H_5OH$, 176). The removal of this alcohol is difficult but can be achieved by drying at 111° *in vacuo.*

Pure crystalline glutathione has a stability in aqueous solution which is disappointing in a respiratory catalyst. The rapid oxidation by atmospheric air of the earlier preparations is now found to be due to the traces of copper present as an impurity. Almost simultaneously papers have appeared from Veogtlin, Johnson, and Rosenthal (*J. Biol. Chem.*, 1931, **93**, 435–53), and N. W. Pirie (*Biochem. Journ.*, 1931, **25**, 1565–79) dealing with the activity of a variety of metals in promoting the atmospheric oxidation of glutathione. Both are agreed as to the great activity of copper in this connection, but differences of technique make it difficult to compare their results. Thus, Pirie used hydrogen peroxide and the other authors atmospheric oxygen for the oxidation. These latter used a phosphate buffer for stabilising the reaction, a fact which accounts for an apparent contradiction between the two papers. The latter authors find very little activity attributable to iron, whereas Pirie finds this metal to have an activity comparable with that of copper provided phosphate and pyrophosphate are absent (oxidation at pH 2·1). There is, according to Pirie, an important distinction between the activities of copper and of iron. The rate of oxidation of glutathione in the presence of copper is proportional to the concentrations of copper and hydrogen peroxide, and independent of that of glutathione. In the case of iron, the concentration of hydrogen peroxide does not control the speed, whilst concentration of glutathione does. Pirie's paper is not confined to the case of glutathione but deals also with the oxidation of cysteine, and with the influence of hæmoglobin and hæmocyanin derivatives on these oxidations.

It is notorious that the estimation of glutathione by Tunnicliffe's iodine titration method gives different results when starch is used as an indicator from those obtained by the use of nitroprusside. The starch method gives the higher results. The addition of an excess of potassium iodide (suggested by Perlzweig and Delrue) lessens this discrepancy, but it has now been shown by N. Gabrilescu (*Biochem. Journ.*, 1931, **25**, 1190–94) that complete agreement between the two methods is only obtained when care is taken to neutralise the solution after the addition of potassium iodide. In these circumstances agreement is obtained between the two indicators not only with pure glutathione but with extracts of liver, yeast, beef muscle, and brain.

The stability in aqueous solution to which reference was made above seems to find a parallel in the inability of pure crystalline glutathione added to washed tissues to produce a

system capable of taking up oxygen. In a series of experiments reported by F. G. Hopkins and K. A. C. Elliott (*Proc. Roy. Soc. B.*, 1931, **109**, 58–88) the behaviour of glutathione present in fresh liver tissue was studied during survival respiration. In the fresh tissue glutathione is exclusively in the reduced form, but it was found that surviving tissue gradually used up the substances capable of reducing glutathione, and eventually this substance was found to be present only in the oxidised form. The experiments taken as a whole strongly confirmed the view that the glutathione is acting—indirectly—as a carrier of oxygen from the air to the foodstuffs waiting to be burned. It was found that the oxidation of glutathione in the tissue proceeds normally after all enzymes have been inactivated by heat, but the reverse action, that of accepting hydrogen from some substance requiring to be oxidised, is brought to an end by this treatment.

X-ray Analysis in Biochemistry.—A communication of great value to biochemistry has appeared from S. H. Piper, A. C. Chibnall, and others in the *Biochemical Journal* (**25**, 2072–94, 1931). It arises, on the one hand, out of the work of Francis, Piper, and Malkin (*Proc. Roy. Soc. A.*, 1930, **128**, 214) on the characterisation of synthetic fatty acids of from 14–26 carbon atoms by means of the X-ray analysis of their crystal forms, and, on the other hand, out of the work of Chibnall on the fats and waxes occurring in various vegetable tissues (*e.g.* Channon and Chibnall, *Biochem. Journ.*, 1929, **23**, 168). The straight chain paraffins from $C_{26}H_{54}$ to $C_{36}H_{74}$ were synthesised in a highly pure condition, and in addition to certain physical properties their crystal spacings were determined by X-ray analysis. The paraffins with an odd number of carbon atoms were synthesised by a reduction of the corresponding ketones after the method of Clemmensen (reduction with zinc amalgam in hydrochloric acid, with alcohol present as a common solvent). Purification of the products proved difficult, but was ultimately achieved by a prolonged heating with concentrated sulphuric acid. Of the even-number paraffins some were obtained from the corresponding primary alcohols by reduction of their iodides, and others by electrolysis of the corresponding fatty acids. The fatty acids used were in general the natural acids. For the details of the ketone synthesis the original should be consulted. The crystal structure not only of the paraffins but also of several of the alcohols and ketones was measured, and in addition the structures of several mixtures. From the results certain rules could be deduced for the identification of mixtures by the X-ray method. Unfortunately, the position is rendered much less simple from the point of view of the X-ray analyst by the fact that only a few of the paraffins have

unique crystal forms, most of them having two alternative forms, and at least one (*n*-hexacosane) having three. The work of the organic chemist is, however, aided by this same circumstance, for it is recorded by these authors that in addition to the melting-point of a paraffin it is possible also to determine two transition temperatures at which a change in crystalline form occurs, and it is their experience that the lower of these two temperatures is generally more affected by the presence of impurities than the melting-point itself. It is therefore recommended as a better criterion of purity, and the necessary measurements of the pure paraffins are listed. Although the melting-points of all the paraffins, even and odd members of the series, lie on a smooth curve, these transition temperatures form two series, one for the even and one for the odd paraffins.

A practical example of the value of these considerations in the analysis of complex mixtures derived from natural sources is given in a second paper by these authors on the wax constituents of the apple cuticle (*Biochem. Journ.*, 1931, **25**, 2095–2110). Amongst the constituents of the unsaponifiable fraction the following were identified by comparison either direct or after suitable conversion, with standard substances already characterised : *n*-nonacosane, *n*-heptacosane, *d*-10-nonacosanol, *n*-hexacosanol, *n*-octacosanol, and *n*-triacontanol. The paper concludes with a discussion of the metabolism of paraffins in the plant in the light of these findings.

Methylglyoxal.—Increasing attention has been paid during the last few years by biochemists to methylglyoxal (pyruvic aldehyde), and its relation to carbohydrate metabolism. Although no facts of outstanding importance have been discovered recently, there have been a number of smaller advances reported. E. Hoffman and C. Rehberg have put on record a simple method of preparing this aldehyde by a gentle oxidation of oximino acetone with nitrosyl sulphuric acid in aqueous solution. The resulting solution gives on distillation pure methylglyoxal in water (*Biochem. Zeit.*, 1930, **226**, 489–91). The ultra-violet absorption spectrum of the substance, redistilled over barium carbonate, has been measured by F. Fischler, H. Haus, and K. Taufel (*Biochem. Zeit.*, 1930, **227**, 156). Pure dextrose solution was found to have no ultraviolet absorption until treated with dilute alkali, when the absorption spectrum of methylglyoxal appeared. Ultimately, in confirmation of the experience of earlier workers, lactic acid could be isolated from the solution, together with smaller amounts of acetic and formic acids.

Although this confirms the idea that methylglyoxal is an intermediary product in the transformation of sugar to lactic acid the experience of H. Spoehr and H. H. Strain (*J. Biol.*

Chem., 1930, **89**, 503–25) is that the action of dilute alkali on methylglyoxal itself results in very little, if any, lactic acid formation, but it is possible that this discrepancy is due to differences in the conditions chosen. These authors report in a later paper that methylglyoxal is formed in acetic acid solution from glyceraldehyde, and from dihydroxyacetone in the presence of certain amines which appear to play the part of catalyst. The reversibility of this change is indicated by the fact that K. Bernhauer and G. Görlich (*Biochem. Zeit.*, 1929, **212**, 452–65) observe the formation of glyceraldehyde from methylglyoxal when the latter is exposed in aqueous solution to magnesium or calcium carbonate.

Neuberg and E. Simon have introduced a technique of estimation of methylglyoxal, pyruvic acid, acetaldehyde and lactic acid, of which the first stage is the precipitation of the hydrazones of the first three compounds by the use of 2-4-dinitrophenylhydrazine, leaving the lactic acid in solution ready to be estimated. Sodium carbonate solution extracts from the mixed hydrazones that of pyruvic acid, and finally 94 per cent. alcohol separates the remaining two by dissolving the hydrazone of acetaldehyde. All three hydrazones are ultimately weighed (*Biochem. Zeit.*, 1931, **232**, 479–84).

Quite a number of papers have recently been devoted to the production of methylglyoxal from hexosediphosphoric ester—generally used as the magnesium salt—under the influence of different tissue extracts. Thus it is reported by C. P. Suñer Bayo (*Biochem. Zeit.*, 1929, **213**, 489–94) that macerated yeast extracts achieve this conversion with a theoretical yield: according to E. Widmann (*Biochem. Zeit.*, 1929, **216**, 474) blood corpuscles prepared in a special manner give a 75 per cent. yield, whilst C. Fromageot (*Biochem. Zeit.*, 1929, **216**, 467) finds similar activity in macerates of B. coli and also in preparations of the organisms dried with alcohol-ether and acetone. C. Neuberg and M. Kobel record the formation of considerable quantities of both methylglyoxal and of pyruvic acid from magnesium hexosediphosphate in a yeast fermentation under the influence of a number of plasmolytic agents (*Biochem. Zeit.*, 1930, **229**, 225). Finally, E. Sym (*Biochem. Zeit.*, 1931, **233**, 251) has reported that the action of a muscle powder preparation (pike muscle) on the same substrate was to produce both methylglyoxal and lactic acid. The metabolism of muscle in the presence of sodium sulphite was the subject of an investigation of E. M. Case and R. P. Cook (*Biochem. Journ.*, 1931, **25**, 1319–35). The use of sodium sulphite was first recommended by Neuberg to side-track any intermediates of an aldehydic or ketonic nature. Pyruvic acid was found to appear in minced rabbit muscle under the influence of sodium

sulphite, though in its absence only methylglyoxal could be demonstrated (the method of isolation was essentially that of Neuberg given above). From a considerable variety of careful experiments they formed the surprising conclusion that pyruvic acid is probably a precursor of lactic acid and is formed only in anaerobic conditions, although its formula suggests that it should be the first oxidation product of lactic acid.

Alongside these papers on methylglyoxal there have appeared a group of communications of which the central interest is the enzyme glyoxalase, found in a wide variety of tissues and shown originally by Dudley to convert substituted glyoxals (*e.g.* methylglyoxal) into the corresponding α-hydroxy acids (*e.g.* lactic acid). The known distribution of this enzyme has been increased latterly by the report of Sufier Bayo (*Biochem. Zeit.*, 1929, **213**, 495–500) of its presence in the leaves of the lime tree (*Tilia grandifolia*). H. Inoue (*Journ. Biochem. Tokio*, 1931, **13**, 369) records that after removal of the glyoxalase from liver extracts by a special method outlined in his paper, these extracts become capable of a highly efficient conversion of hexosephosphate into methylglyoxal, the full conversion into lactic acid having been stopped half-way. In view of the recently discovered ability of iodoacetic acid to inhibit the production of lactic acid in muscles, Dudley has examined the effect of this drug on the glyoxalase activity of chicken breast muscle, using phenylglyoxal as the substrate and measuring by optical methods the *l*-mandelic acid produced. The drug was found to inhibit glyoxalase activity in much the same manner as the " anti-glyoxalase " of pancreatic tissue. The breast muscles of chickens killed by iodoacetate poisoning were found to have lost much of their glyoxalase activity (*Biochem. Journ.*, 1931, **25**, 439–45).

All these facts lead naturally to the conclusion that methylglyoxal should accumulate in tissues poisoned with iodo-acetic acid, and such has in fact been found to be the case by H. K. Barrenscheen, K. E. Braun, and M. Dreguss, who report that methylglyoxal is produced from added hexosediphosphate by the pulps of several different animal tissues and of yeast in the presence of brom- or iodoacetic acid (*Biochem. Zeit.*, 1931, **232**, 165–80). It was formed together with pyruvic acid from glycogen by muscle pulp under the influence of the drug. P. Vogt-Moller (*Biochem. Journ.*, 1931, **25**, 418–21) has taken this train of thought a stage further. He found no methylglyoxal formation from added hexosephosphate by liver extracts taken from normal animals, whilst added methylglyoxal was readily converted into lactic acid. In the case of animals deprived of vitamin B, however, the formation of methylglyoxal could be demonstrated in experiments of the first type,

and its disappearance did not occur in the second : from which he argues that there is a failure of the methylglyoxalase system in B_1 avitaminosis, and that the symptoms of polyneuritis may be due to intoxication with methylglyoxal. Vogt-Moller used three different methods for the estimation of methylglyoxal and performed his experiments both on mice and on pigeons.

Facts which suggest a link between methylglyoxal and fat metabolism are recorded by M. Henze and R. Müller (*Zeit. f. Physiol. Chem.*, 1930, **193**, 88–96), who have discovered that methylglyoxal reacts with acetoacetic acid spontaneously at ordinary temperatures, producing a highly reactive oxydiketone, $CH_3COCHOHCH_2COCH_3$. A number of derivatives of this compound are described, and some of its reactions. This discovery has an obvious bearing on the ketogenic-antiketogenic balance in cell metabolism, and its possible significance in this connection is discussed by the authors.

PHYSICAL CHEMISTRY. By O. H. Wansbrough-Jones, M.A., Ph.D., Laboratory of Colloid Science, Cambridge.

In *Chemical Reviews* of February 1932, amongst articles contributed to a symposium on the "Kinetics of Homogeneous Reaction," are several which discuss unimolecular reactions. To quote Kassel (*Chem. Rev.* 1932, vol. X, p. 11): "Six years ago the existence of unimolecular reactions constituted the outstanding scandal of physical chemistry. It seemed impossible to deny that the molecules reacting had, on the average, an excess energy which could be calculated from the temperature coefficient of reaction rate in the well-known way. Yet it seemed equally impossible to discover any mechanism by which such activated molecules could be produced as fast as they were destroyed by the reaction." A great part of the difficulty arose, doubtless, from there being but one certain example of a true unimolecular decomposition—that of nitrogen pentoxide. The situation has changed now : there are now known to be at least fifteen reactions that are unimolecular, certain definite characteristics of such reactions have been established, and the theoretical explanation seems competent to explain all these characteristics with the possible exception of certain of the specific effects of inert gases on the rate of reaction.

It would certainly have been unfortunate if this, the simplest type of chemical reaction, had remained definitely obscure. The successive stages by which it has been elucidated are worth considering. The problem of the mechanism by which molecules could be activated was first attacked by suggesting that the molecules were activated by radiation, but : "The radiation hypothesis floundered in difficulties almost from the day of its birth, it managed to survive only by clothing its naturally

simple form in such a maze of complications that for a time no one could be quite sure what it was or what it predicted" (Kassel, *loc. cit.*). It is now well known that Lindemann (*Trans. Far. Soc.*, 1922, **17**, 598) showed that ordinary collision theory was not necessarily inadequate in furnishing a mechanism of activation, providing that the existence of a time-lag between activation and reaction be accepted, and that a transition from a first- to a second-order velocity constant be found at decreased pressures, when the time between collisions and the time between activation and reaction became comparable. On this latter foundation has been built most of the accepted theory; and the stage at which the reaction reverts to second order has provided one of the most useful tests of the accuracy of any theory.

The quantitative expression of this idea became the subject of numerous papers. It was at once evident that the absolute rate of reaction was incorrectly given, being consistently too large to be accounted for by simple collisional activation; but progress was made so soon as it was realised that to represent these complex molecules as having but one squared term available was incorrect. It seems that particular energy states in which the molecule can exist must be postulated, and specific reaction rates for those molecules which are activated must be assumed, and that it is then possible to calculate reaction rates which will agree with the experimental results.

Ramsperger, to whom much of the credit for these conceptions must be given, discusses (*ibid.*, p. 27) the different ways in which the molecule must be considered to be activated. The possible modes are, briefly, that the molecule is activated when, as a whole, it contains energy in excess of a certain amount, with no other restriction as to the amount of energy or its place in the molecule, or secondly, that there must be a minimum amount of energy localised in some particular part of the molecule before reaction takes place, on which view the molecule is activated, when as a whole it contains enough energy, but is not in a state to react until a chance distribution leaves the energy so localised that decomposition follows, thus giving a picture of the time-lag which has to be assumed. Thus a distinction is made between "activated" and "reactive" molecules; and, the rate at which the latter are produced from the former may depend on the amount of energy the molecule has in excess of the minimum necessary for activation. In particular the localisation necessary may be identified with one squared term, or two, as for a single vibrational degree of freedom, leading to similar forms of equation between which the experimental data seems still incompetent to discriminate. The problem of deciding which of the two main theories is

correct is not always easy, and is one to which Ramsperger devotes himself in considerable detail; but his conclusion, that the localised energy theory is in the better agreement with results, is so well supported that it now seems safe to adopt it.

His evidence is worth considering. Firstly, the form of the curve showing the transition from first- to second-order constants is not the same for the two theories; in particular, there is a very marked difference predictable when the total number of squared terms required in the molecule is large. Out of fifteen reactions which he cites as certainly unimolecular, all but three seem to fit a localised energy theory the better; and of these the experimental data for one (propionaldehyde) is apparently a little uncertain, for another (dimethyltriazene) there is little to choose between the agreement between experiment and the two theories, while the third (nitrous oxide) is a case in which only two squared terms are necessary and the distinction between the two theories disappears. The second method of selection is more difficult to test, the localised energy theory requires a lower temperature coefficient in the region where the reaction is second order, but the simple theory demands a nearly constant one. The experimental difficulties of this test are obviously great.

The effect of adding inert gases, or of allowing the products of the reaction to accumulate, is rather interesting. At high pressures, such that the rate of activation has no effect on the rate of reaction, no effect is to be expected, nor is any found; but decreasing the pressure of reactant and adding a compensating amount of inert gas might be expected to maintain the first-order constant over a longer range. This effect is common, occurring either through the reaction products or the addition of inert gas, but the differences in efficiency of different gases are exceedingly marked; in general, the reactant itself or its products are most efficient in maintaining the rate of reaction. For the decomposition of ethers, for example, adding the decomposition products was always effective, hydrogen was nearly as good as the ethers themselves, while helium, nitrogen, carbon monoxide or methane have but the slightest effect. Thus the efficiency of activation or deactivation at the collision of these molecules is to some extent a specific property of the molecules. There are theoretical suggestions which imply that such energy transfers may be highly specific (Kallmann and London, *Z. Phys. Chem.*, B., 1929, **2**, 207; Rice, (*Phys. Rev.*, 1931, **37**, 155). More recently Zener (*Phys. Rev.*, 1931, **37**, 556) has given a quantum mechanical treatment of the problem of the interchange of vibrational and translational energy, which treatment has been applied by O. K. Rice (*loc. cit.* and *Chem. Rev.*, 1932, **10**, 125) to this particular case. It is

fortunately possible to include terms in the calculation which may be identified with particular collisions; and from the results it is shown that hydrogen would be expected to have a greater effect than other gases of greater mass. None the less, even in this favourable case, the transition probability seems to be distinctly low, suggesting that some forty collisions of an activated molecule with hydrogen will be necessary to deactivate it. Now it is definitely true that foreign gases do not have such a large effect in maintaining the reaction rate as would be predicted by assuming complete redistribution at every collision, and here theory and practice are at least in qualitative agreement.

The question arises as to how far it is legitimate to assume complete redistribution of energy at every collision between two molecules of reactant. This assumption is inherent in the general theories. Kassel (*loc. cit.*) shows it may be limited in effect to deciding how often an activated molecule will lose, say, one-fifth of its energy on collision, and then examines the truth and consequences of the assumption. He concludes that, with the single exception of nitrogen pentoxide, there is always a wide margin: the rate of energy transfer may be ten, or a hundredfold, less than that demanded by complete redistribution and still suffer the absolute rate to be accounted for. And lately Kistiakowsky and Nelles (*Z. Phys. Chem.*, 1931, Bodenstein, B. 369) find that the rate of isomerisation of dimethyl maleate seems definitely to require a low rate of activation. There remains then that intractable reaction of nitrogen pentoxide, the first of the unimolecular reactions to be found, which seems insistently irregular, and is certainly a most unfortunate example to have used as a type. Kassel " believes that existent theory does account for the rate of this reaction. This opinion can be maintained, however, only by the most optimistic arguments, and the assumption of redistribution at every collision is an absolute necessity." A loss of one-fifth of the energy would be a sufficient deactivation.

The other assumption that is considered is that of the specific reaction rate of an activated molecule, a fundamental chemical problem describing the chemical mechanism of the decomposition process. In other words, it is required to know precisely what bonds are broken when the molecule breaks up, and it is clear, anyhow, that the two reactions

$$\mathrm{ABC} \rightarrow \mathrm{B} + \mathrm{AC}$$
$$\text{and} \quad \mathrm{AB} \rightarrow \mathrm{A} + \mathrm{B}$$

include most of the known examples, and such mechanisms are in agreement with the idea that a localisation of energy in

some particular degree of freedom is essential. There seem to be three main conceptions of the physical nature of the reaction process: the first, the classical picture, involving the activation of a particular degree of freedom; the second, the "radioactive analogy," in which the reaction process is a leak through an energy wall; and the third, the picture comparable to the Auger effect: "The non-radiative transition of a system from a state in the discrete region of its energy spectrum to one in the continuum." Of these the second turns out to be bad in conception and nearly useless in practice. The third inevitably describes such unimolecular reactions, but may be an unnecessarily complicated method of doing so, and Kassel concludes with the comforting remark that "it may be hoped that unimolecular reactions have an essentially classical mechanism." All the same, it should be realised that the now familiar quantum mechanical treatment of activation energies gives at once the result that the specific reaction rate increases as the energy in the molecule increases above the bare activation energy (Eyring, *Chem. Rev.*, 1932, **10**, 112).

Oxides of nitrogen continue to provide the most puzzling examples. Nitrogen pentoxide has been discussed above. Nitrous oxide, the simplest known molecule decomposing as a single molecule, has a peculiarly low specific reaction rate. Originally believed to give a bimolecular reaction, the decomposition of nitrous oxide at low pressures was shown by Volmer and Kummerow (*Zeit. Phys. Chem.*, B. 1930, **9**, 141) to be accelerated by inert gases, indicating a possible unimolecular type of reaction, and later Volmer and Nagasako (*ibid.*, 1930, **10**, 414) actually found a first-order reaction velocity constant at pressures between one and ten atmospheres, and hence the second-order reaction found by Hinshelwood and Burk (*Proc. Roy. Soc.*, A. 1924, **106**, 284), would lie in the range in which the unimolecular decomposition had reverted to second order. Musgrave and Hinshelwood (*Proc. Roy. Soc.*, A. 1932, **135**, 23) now enquire what the low-pressure unimolecular reaction may be. They establish the existence of a unimolecular decomposition at pressures between half and one atmosphere, proceeding simultaneously with the known second-order decomposition, and moreover, show that the first-order rate constant has its limiting value, but below about 50 mm. pressure it also falls away in the manner characteristic of unimolecular reaction when the times required for activation and reaction are comparable. Thus there are two activation processes at work, and while these authors do not exclude the suggestion that the high-pressure reaction may really involve the direct formation of molecular oxygen from two molecules of nitrous oxide at the moment of their collision, their evidence, that the low-pressure

decomposition is that of a single molecule, including as it does the familiar decrease in rate of reaction and giving a very satisfactory absolute rate, is convincing. It will be remembered that the unimolecular decomposition of ethers is strongly catalysed by iodine vapour (Clusius and Hinshelwood, *Proc. Roy. Soc.*, A. 1930, **128**, 82), a phenomenon which may be explained if the iodine serves to activate specifically a part of the molecule, and this reaction of nitrous oxide is very possibly a second example of a molecule in which two different types of activation for the same transformation are possible.

It is as yet too early to decide whether such processes will turn out to be general, but it will be surprising if this view does not prove to be a stimulating one. It is greatly to be hoped that the boundaries of our knowledge of the internal energy relationships of the molecules which undergo such decompositions will be widened.

The theories of gaseous bimolecular reaction have suffered little change of late, and it seems legitimate to adopt a complacent attitude towards them, and to accept the simple view that immediate activation followed by immediate reaction will account for the known phenomena, and hence no such modifications as have been necessary above, that is to say, an inefficient energy exchange on collision and a specific reaction rate increasing as the energy in excess of the bare energy of activation is increased, need to be incorporated. Bimolecular rates of reaction in solution are accordingly being taken in hand, and their kinetics seem to be less intractable than were commonly believed.

The results to be explained fell naturally into two classes—those in which the observed rate in solution was smaller by a factor of a million or more than the rate calculated for a similar hypothetical gas reaction (Norrish and Smith, *J. Chem. Soc.*, 1928, **128**, 129), and some, such as chlorine monoxide (Moelwyn-Hughes and Hinshelwood, *Proc. Roy. Soc.*, A. 1931, **131**, 178), which decompose in such solvents as carbon tetrachloride at the same rate and with the same energy of activation as they do in the gas phase. Moelwyn-Hughes (*Chem. Rev.*, 1932, **10**, 241) has reviewed the rates at which a variety of other bimolecular reactions proceed in solution, and is able to list forty-six different reactions, in a variety of solvents, members of some five distinct types of organic reaction, in which the experimental rate does not show the enormous discrepancy from the theoretical rate discovered by Norrish and Smith, and which, in the majority of cases, shows a very definite agreement between the two. He is able to conclude that at least in these cases to assume deactivation by the solvent molecules is unnecessary, the relatively minor effects played by the viscosity of the

solvent, the large size (or the possibility of a particular orientation at collision being essential), and the variation of the rate on dilution could account for the difference between the theoretical and the calculated rates of reaction.

Now, the " anomalous " reactions in which the huge discrepancies are found involve the conversion of a halide and a nitrogen or amine base into one molecule of a ternary ammonium salt. Moelwyn-Hughes and Hinshelwood (*J. Chem. Soc.*, 1932, 230) have examined a specimen of this type —the combination of triethylamine and ethyl iodide—in various solvents, and have found the slowest rates in those solvents such as hexane and carbon tetrachloride which are designated normal, that is, which allow chlorine monoxide or the catalytic decomposition of ozone by chlorine to proceed at the normal rate calculated from gas kinetic theory, and conclude that other solvents have a catalytic effect. In all cases the rate is still many powers of ten less than the theoretical rate in the gas phase, but upon examination of the gas reaction it turns out that the rate in the gas phase actually is many powers of ten less than the theoretical. The details show that the reaction measured was largely heterogeneous, but despite that, the rate so measured was only about five times as fast as that in hexane and actually slower than that in carbon tetrachloride. Thus the slowest rate is the normal one, and it is incorrect to ascribe a power of deactivation to the solvent molecules.

A similar result was found with another reaction, the esterification of acetic anhydride and ethyl alcohol ; again there was the parallelism between the very slow rates both in the vapour phase and in normal solvents. Whether the very slow rate so found be due to a " steric " factor, or, as seems more probable (*loc. cit.* and Moelwyn-Hughes and Rolfe, *J. Chem. Soc.*, 1932, 241), to be due to the necessity of an intermediate stage of ionisation as a reversible primary process such as

$$C_2H_5I \rightleftharpoons C_2H_5^+ + I^-$$
$$(C_2H_5)_3N + C_2H_5^+ \rightarrow (C_2H_5)_4N^+$$
$$(C_2H_5)_4N^+ + I^- \rightarrow (C_2H_5)_4NI$$

it is very satisfactory to know that the low rates of these reactions are specific, while the applicability of a modified gas kinetic collision formula to find the rate of reaction in a solution may well be general. Another example (Traill, *Phil. Mag.*, 1932, **13**, 224) is the catalysed muta-rotation of beryllium benzoyl camphor in carbon tetrachloride and chloroform, in which an application of kinetic theory gives a very satisfactory result. The modifications which must be made in the simple collision formula so that it may apply to collisions between

solute and solvent molecules have been re-examined by Moelwyn-Hughes (*J. Chem. Soc.*, 1932, **95**), and he has found that the rates of many unimolecular reactions in solution can be accounted for by assuming that every collision between a solute and a solvent molecule which obeys the necessary energy conditions leads to reaction.

GEOLOGY. By G. W. Tyrrell, A.R.C Sc., D.Sc., University, Glasgow.

Volcanology.—Prof. F. von Wolff has published a further part of the second volume of his great treatise on volcanism (*Der Vulkanismus*, II Bd., Spezieller Teil, 2 Teil, Die alte Welt., 1 Lief., " Der atlantische Ozean," 1931, pp. 829–1111). This part deals with the volcanoes and volcanic rocks of the region of the Atlantic Ocean. The North Atlantic, with its great basalt shield or shields, including Greenland, Spitsbergen, Iceland, Western Scotland, and Northern Ireland, is fully dealt with, although Prof. von Wolff appears to have missed much of the recent British literature in all fields. The Central and South Atlantic region includes the Azores, Ascension, St. Helena, Madeira, Canaries, the Cape Verde Islands, and the Cameroons in West Africa. The Rockall and Porcupine Banks, which are included in this latter section, are more properly associated with the northern or Thulean province of Atlantic igneous rocks.

The National Research Council of the National Academy of Sciences (U.S.), in the course of extended work on the physics of the earth, has published a memoir on Volcanology (*Bull. Nat. Res. Council*, No. 77, " Physics of the Earth—I, Volcanology," 1931, 71 pp.), which contains three papers by prominent authorities. Prof. K. Sapper's contribution, entitled, " Volcanoes, their Activity and their Causes," is practically a summary of his recent book, *Vulkankunde* (1927). He has, however, added a valuable résumé of an important but rather inaccessible memoir by P. Groeber, *Ensayo sobre Tectonica Teorica y Provincias Magmaticas*. Prof. I. Friedlander's contribution is a brief general study of *The Present Condition and the Future of Volcanology*. Prof. T. A. Jaggar's memoir on *The Mechanism of Volcanoes* is perhaps the most vital and stimulating contribution of the three. The conception of volcanism as " a process that is at work in and under the crust everywhere, a thermal remnant of a primitive thermal and gas-evolving process which began when the earth separated from the sun," underlies his argument.

Following up his previous work on the subject (Science Progress, July 1930, p. 24), J. E. A. Kania (" Submarine Volcanic Activity in Relation to Chert Deposits and Climate," *Pan-Amer. Geol.*, vol. LIII, 1930, pp. 259–66) presents data

to show that submarine volcanic activity in the form of vents, lavas, and fumaroles, may yield sufficient heat to oceanic water to ameliorate climate within restricted areas, thus promoting the growth of corals in anomalous situations (*e.g.* Silurian of Arctic regions) and precipitating limestone over wide areas. Cherts interbedded with such series are considered to be due in part to submarine thermal springs, but mainly to the solution of volcanic ash in heated alkaline sea water, from which colloidal silica is precipitated.

In further work on gases in rocks and volcanic gases Dr. E. S. Shepherd has come to some important conclusions (*Carnegie Inst., Washington, Ann. Rept. Director of Geophysical Institute, Year Book No.* 30, 1931, pp. 78–82). The volatiles obtained from active vents and fresh lavas of the same vents are essentially identical, water forming 80–90 per cent. of the total gas content. While no fixed magnitudes can be established, there is a certain regularity in the gas contents of fresh lavas and of fresh intrusive rocks such as granite and diabase. Under standard conditions the lavas yield between 5 and 10 c.c. and intrusive rocks about 30 c.c. of volatiles per gramme of rock. Notable diminution of these amounts invites investigation as to whether the rock has been reheated or baked. Notably larger amounts suggest that alteration, which can often be microscopically demonstrated, has taken place.

In view of the importance of volatile constituents in volcanic phenomena, R. W. Goranson's experiments on the solubility of water in granitic magmas are of considerable interest (*Amer. Journ. Sci.*, vol. XXII, 1931, pp. 481–502). The solubility of water in a glass of melted granite was found to be 3·75, 5·75, 8·15, 8·90, and 9·35 weight per cent. at 0·5, 1, 2, 3, 4 kilobars pressure respectively, at a temperature of 900° C. A natural obsidian gave approximately the same figures. It is concluded that natural rhyolite glasses could not well have more than 10 per cent. of combined water, and glasses with from 8 to 10 per cent. should be extremely rare. Hence it is likely that magmas of granitic composition carry relatively high water contents, and that during their intrusion bursting pressures leading to volcanism should be easily attained.

Prof. H. Tanakadate (*Proc. 4th Pacific Sci. Congr., Java,* 1929, p. 621) has made a useful attempt to classify recent Japanese eruptions as follows: (1) sudden explosion without lava, Bandaisan, 1888; (2) sulphur eruptions, Shiretoko, 1889; (3) crater lake eruption, Kusatsu-shirani, 1897; (4) explosive avalanches with explosive lava, Tokachidake, 1925; (5) swelling mountain with explosive lava, Usu-san, 1910; (6) explosive jets and rising plug, Tarumai, 1909; (7) block lava in crater with explosive jets, Asama, 1910–15; (8) ruptured mountain

flank with blocky outflows, Sakurajima, 1914; (9) fluctuating crater lava and flows, Oshima, 1912; (10) submarine eruptions, Minami-iwo-shima, 1904; (11) subterranean lava movement causing earthquakes, Hakone, 1917. Dr. T. A. Jaggar has provided a valuable summary of this paper (*The Volcano Letter*, No. 323, March 5, 1931).

The type of eruption in which a stiff lava rises slowly to form a volcanic dome or plug has lately been shown to be of worldwide occurrence. Hence Dr. Howel Williams's valuable memoir on "The History and Character of Volcanic Domes" is specially opportune (*Univ. of Cal. Publ. Bull. Dept. Geol. Sci.*, **21**, 1932, 51–146). He discusses the morphology, rate and mode of growth, and internal structure of the domes, and the lithology and petrology of their lavas, in which glassiness is highly characteristic. The plug rises by the pressure of its contained gases, and is expelled from craters or fissures at relatively rapid rates (25 metres a day at Mont Pelée and Tarumai), producing sometimes concentric layering, sometimes a fan structure, but often a viscous spread characterised by irregular fissuring and formation of loose blocks which mantle the steep slopes of the dome. Dr. T. A. Jaggar contributes a useful summary of this memoir to *The Volcano Letter* (March 31, 1932).

T. Ogura describes two groups of basaltic domes, containing respectively 36 and 15 examples, in the prefectures of Hiroshima and Okayama, Japan (*Mem. Ryojun Coll. Eng.* (*China*), vol. III, 1930, pp. 95–116). In both regions the domes occur at the intersections of fissure systems running N.W. to S.E., and N.E. to S.W. Basalt lava is usually too mobile to form domes, and Dr. Ogura attributes the form of these Japanese examples to the comparatively small volumes erupted, whereby the magma was greatly chilled before it arrived at the orifice of eruption. The eruption of greatest volume has indeed taken the form of a flat-topped mesa, not that of a true dome.

We transcribe some comments by Dr. M. A. Peacock (*Geogr. Rev.*, Oct. 1931, p. 699) on Prof. H. Reck's important paper ("Die Masseneruption unter besonderer Würdigung der Arealeruption in ihrer systematischen und genetischen Bedeutung für des islandische Basaltdeckengebirge," *Deutsche Island-forschung*, 1930, pp. 24–49) which is an outstanding contribution to the problem of the origin of basaltic plateaux: "Theoretically a mass eruption might occur at a point, at a line, or at a surface, giving respectively a central eruption, a fissure eruption, or an areal eruption. Central mass eruptions in Iceland are represented by low, widespread lava domes, named Schildvulkane in German, and Dyngja in Icelandic. The lack of a single convincing natural section through such a

central vent in the early Kainozoic basalt plateau leads to the conclusion that central mass eruptions played no important part in the construction of the plateau. Mass eruptions from extended fissures are usually regarded as the most probable plateau-building mechanism ; but although recent eruptions of this type are known in Iceland, the absence of dikes passing into sheets in the plateau points to the absence or insignificance of this mode of eruption in the early Kainozoic. There remains the areal mass eruption, hitherto neglected as a plateau-building mechanism. In opposition to the views of Daly and von Wolff, who regard an areal eruption as the result of an eruptive laccolith melting its way to the surface over a large area, Reck sees the action of typical areal eruptions in groups of irregularly arranged, nearly synchronously active craters connected with a common underlying magma body. Such crater groups are numerous in Iceland and in other volcanic countries. A plateau built by this action would show almost no trace of the mechanism, and thus amongst the most characteristic signs of the action of areal mass eruptions in basalt plateaux would be the very absence of evidence of the manner in which the lavas were erupted."

Prof. J. W. Gregory has also questioned the fissure-eruption mode of origin of basalt plateaux (*Earthquakes and Volcanoes*, " Benn's Sixpenny Library," No. 97, 1929, pp. 34–7) on three grounds : that the lava has not been discharged directly from fissures, but from rows of small volcanic cones situated upon fissures ; that the supposed feeder-dikes often pass through the flows, and cannot therefore have been the channels of supply ; and that abundant tuff and ash deposits, which must have been ejected from central vents, are often interbedded with the flows. The present writer has replied to these points in his own book on *Volcanoes* (" Home University Library," No. 152, 1931, pp. 196–8). The cones and craters built upon the fissures represent the expiring phases of emission when, owing to the slackening of the eruptive impulse, the fissure becomes choked except at a few isolated points. The same fissure may feed many flows, as shown in Hawaii ; consequently, the feeder-dikes should pass through the earlier flows and connect up only with the final flow. The chances are enormously against these sporadic connections of dike and sheet being exposed by erosion ; nevertheless, examples have been described by Fuller and Lee in Western America. There is nothing in the fissure-eruption mechanism to prevent extensive ash beds being formed, but in all known cases the explosive products are of insignificant quantity as compared with the effusive products of the eruptions.

Dr. H. T. Stearns and W. O. Clark have produced an ex-

cellent account of the geology (and water resources) of the Kau District of Hawaii (*Water-Supply Paper No. 616, U.S. Geol. Surv.*, 1930, 194 pp.), the region which contains the active shield volcanoes of Mauna Loa and Kilauea. There is hardly a single aspect of volcanism which is not illuminated in this memoir. The geographical features of the area are first described, then the stratigraphical geology of the entirely igneous formations. There follows a succinct account of the flows from Mauna Loa and Kilauea in historical times, and of the spectacular faulting which has occurred. The great summit craters are regarded as due, not to completely circular faults, but to the coalescence and intersection of elongated arcs of faulting. Volcanic products, types of cones, pit craters, volcanic processes, volcanic explosions, and petrology, are the remaining topics. Perhaps the most satisfying feature of this memoir is the complete demonstration, not only of the reality of fissure eruptions, but of their ability to build up great basalt plateaux, which has recently been challenged as shown above. Not only that, but Dr. Stearns has demonstrated the fact that by far the greater part of the huge shield volcanoes of Hawaii have been built up by fissure eruptions, even the great pit-craters on their summits being only secondary and adventitious features, not, as in true central volcanoes, the main foci of eruption and orifices of magmatic emission.

Two other Hawaiian volcanic domes are described by N. E. A. Hinds (" The Geology of Kauai and Niihau," *Bern. P. Bishop Mus., Honolulu*, Bull. 71, 1930, pp. 1–103). Their characters completely confirm the views of Dr. Stearns as to the origin of these immense structures, and as to the importance of fissure eruption in their construction. Great numbers of dikes cut a lower series of flows in Kauai, and are regarded as the feeders of a second series of lavas. Dr. Hinds states that in a number of places the dikes are clearly flow feeders.

The geology, volcanology, and petrology of other groups of Pacific Islands are dealt with in the following memoirs : L. J. Chubb, " Geology of the Marquesas Islands," *Bern. P. Bishop Mus., Honolulu*, Bull. 68, 1930, pp. 1–71 ; P. Marshall, " Geology of Rarotonga and Atiu," *ibid.*, Bull. 72, 1930, pp. 1–75.

In an important paper on " The Aqueous Chilling of Basaltic Lava on the Columbia River Plateau," Dr. R. E. Fuller (*Amer. Journ. Sci.*, vol. XXI, 1931, pp. 281–300) shows, by excellent field examples, that a fluid lava entering a local body of water would tend to granulate like molten slag, forming a fine bedded breccia which, with continued slow motion of the flow, would gradually advance like the fore-set bedding of a delta. Coarser elongated masses of ropy or ellipsoidal shapes would tend to take up the same inclination as the breccia. He also describes

beautiful examples of pillow-lavas which have resulted from the gradual advance of relatively viscous basalts into small bodies of water. Massive breccias occur which are held to be due to the advance of thick bodies of lava into deep water.

Dr. Fuller has also described certain tensional surface features in the ellipsoidal basalt lavas of the Colombia River plateau (*Journ. Geol.*, vol. XL, 1932, pp. 164–70). These consist of regular angular corrugations on the surfaces of " pillows " between the walls of tension cracks, a surface aptly compared to that of a washing board. These features are believed to have been caused by the distension of a thin glassy crust due to the swelling of the " pillow " as it was rapidly exposed under water.

Prof. J. A. Bartrum describes occurrences of pillow lavas in New Zealand which contain thick, radiate-columnar, ovoid lava-masses, sometimes 80 feet in length. These are regarded as essentially giant " pillows." Some adjacent dikes pass upwards into large spheroidal masses indistinguishable from the " pillows " of normal pillow-lavas (*Journ. Geol.*, vol. XXXVIII, 1930, pp. 447–55).

H. C. Cooke, W. F. James, and J. B. Mawdsley (" Geology and Ore Deposits of Rouyn-Harricanaw Region, Quebec," *Geol. Surv. Canada*, Mem. 166, 1931 (314 pp.), pp. 40–51) describe remarkable structures in the Keewatin lavas of Quebec, some of which it is possible to utilise to determine whether or not these greatly disturbed rocks are " right-way-up." Many of the flows are pillow lavas, with an upper thick zone of " pillows," followed beneath either by rudimentary " pillows " or by extremely fine-grained rock in which the grain size gradually increases towards the base of the flow, attaining its maximum a few inches above the actual base. These criteria of upper and lower surfaces of pillow lavas have been successfully used in determining the attitude of the rocks in folded areas. The authors also describe ropy and brecciated structures in these extremely ancient lavas, and state that pillow structure, although most common in basalt, frequently appears in trachyte, dacite, and even in the rhyolite of the Keewatin Series.

By the study of some Lower Carboniferous lavas in Renfrewshire, Kainozoic lavas of Skye, and a recent lava from Etna, Dr. W. Q. Kennedy (*Geol. Mag.*, vol. LXVIII, 1931, pp. 166–81) has been able to show that the composite character may occur in effusive as well as in intrusive rocks. The Renfrewshire examples are mugearitic basalts at the bases, and Markle basalts in the upper parts of the flows ; the Skye examples, similarly, are mugearites and porphyritic basalts. Dr. Kennedy explains their composite character by assuming that the lava changed in composition during extrusion. Sometimes the later porphyritic basalt overrode the non-porphyritic lower member,

and extended beyond its boundaries ; the reverse case is also known. While bilateral symmetry is characteristic of composite intrusive bodies, asymmetry seems to be a good criterion of composite lavas.

Dr. W. J. McCallien (*Geol. Mag.*, vol. LXX, 1932, pp. 135–7) notes the possible occurrence of a composite lava of Calciferous Sandstone age in Kintyre. Both members are basalts, and are distinguishable only by the parallelism of feldspars in one, and by the fact that an infilled vesicle appears to have been cut and sheared off by the second lava.

Descriptions of recent activity in Mediterranean volcanoes are given in the following papers: I. Friedlander, " Der Tätigkeit des Vesuv in der zweiten Hälfte des Jahres 1928," *Zeitschr. f. Vulk.*, vol. XII, 1929, pp. 47–51 ; A. Rittmann, " Der Vesuvausbruch im Juni," 1929, *ibid.*, pp. 305–22 ; " Der Tätigkeit des Vesuv im Jahre 1930," *ibid.*, vol. XIII, 1931, pp. 249–51 ; A. Heim, " Der Stromboli Mitte Mai 1872," *ibid.*, vol. XIV, 1931, pp. 1–12 ; H. Reck, " Der Stromboli im Oktober 1925," *ibid.*, pp. 13–21 ; K. Sapper, " Der Stromboli im September 1929," *ibid*, pp. 22–37 ; F. Bernauer, " Zur Kenntnis der periodischen Ausbrüche des Stromboli im April 1930," *ibid.*, pp. 38–46 ; A. Rittmann, " Der Ausbruch des Stromboli am 11 Sept. 1930," *ibid.*, pp. 47–77 ; E. Lengyel, " Der Etnaausbruch im Jahre 1928 und sein Gestein," *Act. Lit. Sci. Reg. Univ. Hungar. Francisco-Josephinae. Act. Chem. Min. et Phys.*, Tom. 1, fasc. 2, Szeged, 1929, pp. 128–47 ; H. Philipp, " Beobachtungen über die letzte Aetna-eruption und die augenblickliche Phase des Vesuv und des Insel Vulkano," *Forsch. u. Fortschr. Berlin*, Feb. 1929, 2 pp. reprint ; I. Friedlander, " Der Aetna-Ausbruch 1928," *Zeitschr. f. Vulk*, vol. XII, 1929, pp. 33–46 ; C. Haeni, " Veränderungen am Etna seit dem Ausbruch von 1928 bis Ende 1930," *ibid.*, vol. XIII, 1931, pp. 245–9. In regard to Etna, Prof. Friedlander shows that the eruption of November 1928 marked the return of the lava to the E. to W. system of fissures. The last outbreak in this fissure zone occurred in 1865. The six main eruptions which took place between 1865 and 1928 all broke out from the N. to S. system of fissures.

Prof. H. Reck describes the so-called " Nautilus " eruption at Santorin as a dome-like uplift of the surface of the 1925 lava by a still rising subjacent magma (*Zeitschr. f. Vulk.*, vol. XIII, 1930, pp. 25–50). It was not built of newly erupted material. The type is designated by Reck as *epigenetic*—a parasitic cone of volcanotectonic origin rising within the periphery of a main volcano subsequent to its extinction.

In two papers Dr. N. L. Bowen presents the preliminary results of his visit to Central African volcanoes of the Mufumbira

(Virunga) region (" Central African Volcanoes in 1929," *Trans. Amer. Geophys. Union, 10th and 11th Annual Meetings*, 1929 *and* 1930, pp. 301–7 ; " Volcanoes of the African Rift Zone," *Carn. Inst., Washington, Ann. Rept. Director of Geophys. Lab., Year Book No. 29 (1929–30)*, 1930, pp. 73–6). Two of the eight great cones in this region were active, and one of them, Namlagira, exhibited a huge circular summit caldera, with an interior terrace, lava pits, fountains, " islands," and sink-holes, of Kilauean character. The Mufumbira volcanoes are definitely associated with a series of cross faults that intersect the main Rift Valley faults.

A total of thirteen volcanic cones were noted by Dr. W. A. Macfadyen amongst the Zebayir Islands in the Red Sea (*Geol. Mag.*, vol. LXIX, 1932, pp. 63–7). Most of them were loose cinder cones which were formed in post-raised beach times. The erupted rocks are basalts poor in olivine, although one rock seems to be so rich in olivine as to merit the term oceanite.

The geology and volcanism of the Krakatau Group have been investigated by C. E. Stehn (Java, 1929, 55 pp. ; see H. Reck, *Zeitschr. f. Vulk.*, vol. XII, 1930, pp. 335–7), who distinguishes four periods in the history of this volcano, including the colossal explosion of 1883. In 1928 numerous steam explosions took place under water in the old sea-flooded crater (H. Reck, " Übersicht über die Tätigkeit des Krakatau im Jahre 1928," *Zeitschr. f. Vulk.*, vol. XII, 1929, pp. 52–5 ; " Ein Rückblick auf den Ausbruch des Krakatau von 1928–1930," *ibid.*, vol. XIV, 1931, pp. 118–34). Krakatau seems to have erupted a very acid andesite or dacite (65–70 per cent. silica) in alternation with a basaltic type of lava (50–53 per cent. silica).

In his paper entitled, " Mt. Katmai and Mt. Mageik," Dr. C. N. Fenner (*Zeitschr. f. Vulk.*, vol. XIII, 1930, pp. 1–24) describes his interesting pioneer visits to the crater floors of these volcanoes. Great steam jets, explosive mud geysers, and much fumarole activity were found. Dr. Fenner also shows that the attitudes of the strata that build the Alaska Peninsula are essentially horizontal, and consequently the theory that it represents an arc or festoon formed as a fold or wrinkle in front of an advancing segment of the earth's crust appears to be untenable.

Dr. M. A. Peacock describes the great Modoc lava field of North California, the natural features of which are so striking that a portion of the region has been set aside as a national monument (*Geogr. Rev.*, vol. XXI, 1931, pp. 259–75). In this field there are hundreds of square miles of jagged and corded lava, scores of perfectly preserved cinder cones, and barren mountains of volcanic glass representing effusive domes of impressive dimensions.

Evidence of recent volcanism in British Columbia is supplied by N. F. G. Davis in a description of the Clearwater Lake area (*Geol. Surv. Canada, Summ. Rept., 1929*, Pt. A, 1930, pp. 274–96). Flows of block lava (basalt) with red scoriaceous surfaces occur on Ray Mt. Other flows have typical ropy structures, including the most recent flow which is strikingly fresh. These rocks are unglaciated, and as yet support no grass, only a few small birch and poplar trees. They are to be correlated with the recent volcanics of the Cascade Range of the United States.

The following are important papers on Central American and Mexican volcanoes: K. Sapper and F. Termer, "Der Ausbruch des Vulkans Santa Maria in Guatemala vom 2–4 Nov. 1929," *Zeitschr. f. Vulk.*, vol. XIII, 1930, pp. 73–101; I. Friedlander, "Über die mexikanischen Vulkane Pico de Orizaba, Cerro de Tequila, und Colima," *ibid.*, pp. 154–64.

The geographical description of the South Sandwich Islands, by Dr. S. Kemp and A. L. Nelson ("*Discovery*" *Reports*, vol. III, 1931, pp. 133–98), contains numerous volcanological observations on these little-known islands of the South Atlantic Ocean. Five of the eleven islands exhibited definite volcanic activity with the emission of smoke and fumes. Three showed no signs of activity, but evidences of warmth in the presence of patches of snow-free ground. A magnificent series of illustrations shows cones and craters in all stages of dissection, and a submerged crater was discovered by soundings between Cook Island and Thule Island.

In his paper on "The Western Andes and their Relation to the Tertiary Coast Belt, Ecuador," Dr. G. Sheppard (*Geol. Mag.*, vol. LXVIII, 1931, pp. 481–94) gives reasons to think that primary structural features, such as block-faulting and overthrusting in the sedimentary rocks, may have been caused by a foundering of the strata upon the irregular cooling surfaces of injected igneous rocks. He also finds that in many places the surface of an igneous injection is covered by a zone of breccia consisting of fragments of sedimentary rocks. He suggests that the shattering of the sedimentary cover was caused by settling consequent upon cooling contraction of the igneous body, and describes the breccia thus formed as "founder-breccia."

In the Old Granites of South Africa dolerite intrusions of the Karroo episode are overwhelmingly dike-like in form, but rare cases are known of more or less horizontal sheets, of which examples are described by Dr. L. J. Krige (*Trans. Geol. Soc., S. Africa*, vol. XXXII, 1930, pp. 57–60). The main sheet is traceable over an area 30 miles long by 10 miles wide. Dr. Krige explains the horizontal injection into unbedded granite as due to the development of horizontal planes of weakness

consequent upon tangential pressure arising from heat expansion of the granitic crust.

In the memoir, by J. E. Richey and H. H. Thomas, on "The Geology of Ardnamurchan, North-west Mull, and Coll" (*Mem. Geol. Surv. Scotland*, 1930, 393 pp.), the last of the five main Tertiary volcanic regions of the West of Scotland has now been exhaustively dealt with. These great ancient volcanoes must now be the most closely described of any in the world. They are remarkable for their ring structures, of which those of Ardnamurchan are certainly not the least perfect. The phenomena of the intrusion of ring-dikes and cone-sheets are well displayed in three centres which were in successive operation. Around the earliest centre in the eastern part of the district are arranged volcanic vents, major intrusions, and cone-sheets, all more or less elongated in concentric arcs. The igneous activity then shifted to a second centre situated on the west, around which doming of the adjacent sediments occurred, and two intrusions of cone-sheets were separated by a period of ring-dike formation. Finally, the igneous activity migrated to a focus situated midway between the two earlier centres, around which ring-dikes were injected with almost perfect concentricity. Cone-sheet intrusion also took place, but only on the south side of the focus.

In a recent memoir J. E. Richey (" Tertiary Ring Structures in Britain," *Trans. Geol. Soc. Glasgow*, vol. XIX, Pt. 1, 1932, pp. 42–140) has given a masterly summary of the general characteristics of ring-structures. He describes the ring-structures of Ardnamurchan, Mull, Skye, Rum, St. Kilda, and Arran, in Scotland; and three examples, Slieve Gullion, Carlingford, and Mourne Mts., in Ireland. The descriptive part is followed by a general discussion of ring-dike and cone-sheet complexes, the possible upward and downward extensions of these intrusive bodies, the magmas reservoirs whence they were derived and their possible depths, the mode of origin of ring structures, uplift due to cone-sheet intrusion, central subsidence in relation to ring-dike intrusion, magmatic pressure in relation to ring structures and radial fissures, the composition of the regional magma, and the order, basic to acid, of its intrusion. From this brief summary it can be seen that this memoir constitutes one of the most important contributions to igneous geology of recent years.

Ring structures are now beginning to be recognised in other parts of the world. An almost perfect example of a ring-dike, eight miles in diameter, and consisting of nordmarkite, is reported by L. Kingsley from the Ossipee Mts. of New Hampshire (*Amer. Journ. Sci.*, vol. XXII, 1931, pp. 139–68). It surrounds a subsided cylindrical mass of basalt, andesite, and

quartz-porphyry lavas, and has welled up along the peripheral circular fault. A granite was subsequently injected into the central part of the structure.

ZOOLOGY. By F. W. Rogers Brambell, Ph.D., D.Sc., Professor of Zoology, University College of N. Wales, Bangor.

It has been known for many years that the body fluids of marine invertebrates and the blood of elasmobranchs are approximately isotonic with sea-water, whereas the osmotic pressure of the blood of marine teleosts is considerably lower. This is the result, in the case of the invertebrates, of the concentration of soluble salts in the body fluids being approximately equal to that of the surrounding sea-water. In the elasmobranchs the isotonic condition of the blood is largely due to the high concentration of urea, although soluble salts also play a part. Thus the blood and surrounding sea-water are in osmotic equilibrium, but, unlike the invertebrates, the concentrations of individual solutes in each are different. It has been shown recently by Margaria (*Proc. Roy. Soc.*, B. **107**, 1931) and by Hukuda (see Margaria) that when a typical marine invertebrate, or an elasmobranch, is transferred to a diluted medium an equalisation of osmotic pressure between the body fluids and the external medium takes place. It is of considerable interest to determine how the equilibrium is maintained in the two cases. Hukuda (*Jour. Expt. Biol.*, **9**, 1932) describes an investigation of this problem in a recent paper. Obviously the equilibrium must be maintained either by the passage of water through the bounding membrane of the animal or by change in the amount of salts or other dissolved substances in the internal medium. If the former is the method, then the animal when placed in a hypotonic medium should increase in weight owing to the entrance of water into the animal. If the latter is the mechanism of equilibration the weight of the animal should remain constant after transference to a dilute medium. Hukuda found that the weights of several species of crustaceans increased slightly in a dilute medium consisting of sea-water, but not sufficiently to account for the equalisation of osmotic pressure. Therefore the equalisation must occur mainly by the disappearance of salts from the body-fluids, probably by diffusion through the bounding membrane. Thus the bounding membrane of marine crustaceans is permeable to water and also to salts. The slight osmotic swelling observed suggests that the permeability to salts is not quite perfect. Similar experiments were performed on dog fish by keeping them in $\frac{7}{8}$ and $\frac{4}{5}$ sea-water. The increase in weight observed agreed closely with the calculated values of the amount of water necessary to dilute the blood to the requisite extent to re-establish the osmotic equilibrium with

the external medium. It would appear, therefore, that the equilibrium in elasmobranchs is maintained by the diffusion of water and not of solutes through the bounding membrane, and that this membrane is semi-permeable in consequence.

It has been known for a long time that the blood of the hag-fish, *Polystotrema*, is also approximately isotonic with sea-water, whereas it is probable that in the marine lampreys this is not the case. Bond, Cary, and Hutchinson (*Jour. Expt. Biol.*, **9**, 1932) have investigated this problem in *Polystotrema*, and have found that the chloride content of the blood, in specimens kept in sea-water of varying salinity from 2·5 to 4·0 per cent., varies in a linear manner with that of the external medium. They conclude that the greater part of the osmotic pressure of the blood is due to the chlorides. Moreover, they failed to detect any swelling in the hypotonic media. It is clear that the blood of *Polystotrema* is comparable to the body fluids of marine invertebrates, and that the gills or some other part of the body-wall are permeable to both water and salts. It has been suggested that marine teleosts have inherited from fresh-water ancestors the power of maintaining the osmotic pressure of their blood at a constant value considerably lower than that of the external medium. Thus the condition of the blood of *Polystotrema*, isotonic with the surrounding sea-water, is interpreted as indicating that the hag-fish have had no fresh-water ancestors.

The osmotic properties of Medusæ have been investigated by Bateman (*Jour. Expt. Biol.*, **9**, 1932), who finds that they show no osmotic regulation independently of the surrounding medium. It is also shown that the total water in the jelly is osmotically free, and it follows that nearly all the electrolyte present is also uncombined. The statement that has found its way into the literature, that Medusæ contain 99·8 per cent. water, is shown to be incorrect.

The physiological significance of the urea in the blood of elasmobranchs has been investigated from a different angle by Simpson and Ogden (*Jour. Expt. Biol.*, **9**, 1932). It is well known that carbon dioxide and urea, as the end products of metabolism, are present in the blood of all vertebrates, and that they are maintained at a remarkably consistent level of concentration. It is also well known that the concentration of carbon dioxide in the blood regulates respiration by stimulating the respiratory centres. Simpson and Ogden have attempted to explore the problem of whether the concentration of urea may not also have some definite physiological significance. Owing to the unusually high blood-urea level, and the statement of Mines that the heart will only beat in a medium rich in urea, elasmobranchs were chosen as suitable material. The concentration of urea in the blood in relation to the optimum conditions for beating

of the heart of the dog-fish were investigated. It was found that diminution of the urea content of the surrounding medium was followed by decrease in amplitude of the beats of the excised auricle. Recovery from this decrease could be produced by restoring the concentration of urea. The beating of the auricle was not maintained when the urea of the surrounding medium was replaced by sucrose, thio-urea or sodium sulphate in iso-osmotic concentrations. The failure of these three widely different substitutes to maintain the beat strongly suggests that urea is necessary for some other reason than its purely osmotic effect.

The development and function of the heart and pericardium in the Echinodermata is the subject of a paper by Narasimhamurti (*Proc. Roy. Soc.*, B. **109**, 1932). The pericardial vesicle is shown to arise from the posterior part of the right anterior cœlom as a solid bud, which becomes hollowed out and extends dorsally. The heart is formed in late plutei by the invagination of the floor of the vesicle. The spongy tissue underneath invades the invaginated floor of the vesicle in late brachiolariæ. In the adult star-fish and sea-urchin the vesicle is in the form of a closed sac on the dorsal side directly under the madreporite. It is maintained that the pericardial vesicle of Echinoderms corresponds in origin and structure to the pericardial sac of *Balanoglossus*. The invaginated floor of the vesicle, with the inpushed spongy tissues, in Echinoderms is compared with the heart of *Balanoglossus*. It is claimed that this homology constitutes one of the strongest proofs of the affinity of the Echinodermata with the Enteropneusta. The fluid contained in the heart of the Echinoderm larva is shown to be blastocœlic fluid, which is rich in nutritive substances exuded into it by the stomach cells. This fluid is pumped forward by pulsations in the floor of the vesicle. The rate of pulsation of the heart of *Echinus miliaris* is about four times that of *Asterias rubens*. It was found that $MgCl_2$ in low concentrations decreased the number of beats per minute, but that the rate of beat returned to normal after its removal. Solutions of KCl had an exactly opposite effect.

Since Eggleton and Eggleton demonstrated in 1927 the presence of labile phosphorus in muscular tissue, our knowledge of its great importance in muscular contraction has grown rapidly. It is now known to be present in vetebrate muscle in the form of creatine phosphate. Eggleton and Eggleton (*Jour. Physiol.*, **65**, 1928), however, failed to find creatine phosphate in a number of invertebrates examined. In the same year Meyerhof and Lohmann (*Biochem. Z.*, **196**, 1928) discovered that phosphagen is present in crustacean muscle in the form of arginine phosphate. Subsequently Meyerhof (*Archi. Sci. biol.*

Napoli., **12**, 1928) found arginine phosphate to be present in a number of other invertebrates. This led to the assumption that creatine phosphate is characteristic of vertebrate muscle, and that arginine phosphate is as characteristic of vertebrate muscular tissue. Meyerhof later (*Die Chemische Vorgänge in Muskel*, Berlin, 1930) expressed the view that the development of the creatine phosphate in vertebrates from the arginine phosphate of invertebrates should be regarded as a chemical mutation. Needham and others, in a recent paper (*Proc. Roy. Soc.*, B. **110**, 1932), describe the results of a systematic survey of the phosphagens of Invertebrates. They found arginine phosphate in all the Phyla examined. Among the Cœlenterata it was found in the Centophore *Pleurobrachia*, but was not found in *Anthea*, the only Actinozoan examined. The evidence suggests that arginine phosphate may be associated with ciliary, as well as muscular, movement. Creatine phosphate was found in the jaw muscle of *Strongylocentrotus* among the Echinodermata, and in *Balanoglossus* among the Enteropneusta, but was absent from the Urochodata (*Ascidia*). It was known from previous work that creatine phosphate alone is present in *Amphioxus* and many species of vertebrates. Thus, so far as phosphagens are concerned, *Amphioxus* resembles the vertebrates and *Ascidia* resembles the invertebrates, while *Balanoglossus* and one Echinoderm possess both creatine and arginine phosphate. It is suggested that these biochemical results support the theory of the phylogenetic affinities of the Echinodermata, Enteropneusta, and Vertebrata.

The permeability to water and certain other properties of the surface of the egg of *Psammechinus miliaris* immediately prior to and after fertilisation until the first cleavage have been investigated by Hobson (*Jour. Expt. Biol.*, **9**, 1932). Volume changes in the eggs, following osmotic changes in the surrounding medium, were recorded by a photographic method, which is described. The rate of entrance of water into the eggs from hypotonic sea-water was found to increase immediately after fertilisation, reaching a first maximum after about 3 minutes. It then falls to a relatively low value at about 5 minutes, and subsequently increases steadily to a second maximum, which is attained about 35 minutes after fertilisation. It remained steady at this second maximum until shortly before cleavage, when it fell sharply in the only experiment continued so far.

Several different types of plasmolysis occur in hypertonic solutions, and are characteristic of the stage of development which the egg has attained. The type of plasmolysis is said to be determined principally by the physical properties of the egg surface. Investigation of the rate of cytolysis in tap-water indicated that a susceptible period is followed by a period of

resistance during the first 5 to 10 minutes after fertilisation. It is probable that the degree to which the cell surface will withstand stretching, as well as the rate of entrance of the water, is a significant factor conditioning the rate of cytolysis. The rate of cytolysis in extremely hypertonic solutions of sea-water increases to a maximum at 5 to 10 minutes after fertilisation and then decreases. It is concluded that the relation between the rate of cytolysis and permeability is uncertain.

In another paper (*ibid.*, 1932) Hobson describes an investigation of the vitelline membrane of the eggs of *Psammechinus miliaris* and *Teredo norvegica.* It is generally believed that such a membrane is present on the surface of the unfertilised egg, and that at fertilisation it is elevated from the surface and gives rise to the fertilisation membrane. Hobson finds that microscopic examination of the unfertilised eggs of both these forms reveals only the presence of a thin zone, free from granules, over the surface, but does not show whether or not it is continuous with the underlying cytoplasm. A definite membrane cannot be separated by means of a micro-dissection needle in either species. Plasmolysis of the egg of *Psammechinus* results first in the egg shrinking smoothly, and later becoming wrinkled, while cytolysis in tap-water merely results in the egg swelling but remaining smooth and spherical. These facts point to the existence of an elastic solid surface layer. Plasmolysis of the egg of *Teredo* results in the separation of a clear membrane, while cytolysis, which is followed by bursting and dispersion of the cytoplasm, leaves a crumpled membrane. It is concluded that the unfertilised egg in both species is surrounded by an elastic vitelline membrane, firmly attached to the egg surface, which is much thicker in *Teredo* than in *Psammechinus.* It is suggested that in the induction of artificial parthenogenesis one effect of hypertonic solutions may be a loosening of the attachment of the vitelline membrane to the egg surface.

Chambers and Fell (*Proc. Roy. Soc.*, B. **109**, 1931) describe an extensive series of micro-operations on cells in tissue cultures. The technical difficulties of the application of micro-dissection methods to tissue cultures are very great, but were overcome, largely by the use of a special dark-ground illumination apparatus, which is described. A variety of cells, including fibroblasts, intestinal and pigmented retinal epithelial cells, macrophages, skeletal myoblasts, and cells in mitosis, were operated upon. The results of cytoplasmic and nuclear puncture, tearing of the surface membrane, prodding, etc., are described in detail. The cell membrane was found to be stiffer than the cytoplasm, and the elasticity exhibited by the cells seemed to be primarily due to it. Puncturing of the cytoplasm, pushing about cytoplasmic

granules, and cutting mitochondria into two did not seriously affect the cells, but a quick tear of the cell membrane resulted in degeneration. The oval nuclei could be deformed by prodding. They had a definite membrane and a fluid interior, containing no visible structures except one or two nucleoli. The nucleoli could be cut in two, but nuclear degeneration quickly followed puncture of the nuclear membrane. Nuclear degeneration resulted in degenerative changes in the surrounding cytoplasm, and of the whole cell when only one nucleus was present in it. Puncture of one nucleus in binucleate cells resulted in degeneration of that nucleus and of the neighbouring cytoplasm, but was frequently limited to the vicinity of the injured nucleus, the cell returning to the normal mono-nucleate condition except for the crumpled remnant of the second nucleus in the cytoplasm. The symptoms of cellular degeneration following injury are described. The long multinucleated skeletal myoblasts derived from the limb of a six-day chick were made to twitch repeatedly, with a refractory period between each twitch, by pricking with a needle. Fibroblasts in mitosis were found to be very susceptible to injury. All cells, possibly excepting macrophages, were found to be attached to their neighbours at some points. When a cell is injured it shrinks away from its neighbours, but the effect of the injury is not transmitted to them. Such a transmission of injury was only observed from one daughter cell to the other during the period following mitosis, while the two were still connected by a protoplasmic bridge. Macrophages were found to be attracted from a distance to a cell which had degenerated through mechanical injury.

During the last few years an increasing amount of research has been carried out on the effects of various kinds of radiations on living cells. Spear (*Proc. Roy. Soc.*, B. **106**, 1930), studying the effects of gamma radiation from radium on tissue cultures, found that the first effect exhibited is a temporary cessation of growth and mitotic activity, followed later by the reappearance of mitosis, which may persist for some time. Finally, growth again ceases, cellular degeneration follows, and results, if the dose was lethal, in death. Thus it is not the initial inhibition of mitosis but the delayed effect which is fatal. A similar effect in chick embryos exposed to a single dose of X-rays is described by Butler (*Jour. Expt. Biol.*, **9**, 1932). The tissue examined was the neural tube, which consists of two types of cells. The germinal cells are conspicuously active in mitosis, and are restricted to the innermost layer of the neural tube. The mantle layer forming the main mass of the neural wall is composed of cells with nuclei in the resting state. Radiation with a non-lethal dose of X-rays resulted in an initial period in which mitosis ceased in the germinal cells, followed by a period

of recovery in which mitotic activity restarted. A final period, marked by degeneration among the cells in the resting state, ensued, and was by far the most severe effect of the radiation. After recovery from this the tissue returned to normal.

Canti and Spear (*Proc. Roy. Soc.*, B. **105**, 1929) showed that tissue cultures exposed to radiation from radium exhibited a period of compensatory increase in mitotic activity following the initial fall in mitosis. In a recent paper Spear (*Jour. Expt. Biol.*, **9**, 1932) has attempted to carry this work further by examining the effect of two irradiations with an interval between, and comparing the results with those obtained from a continuous irradiation. It is shown that two exposures of 2½ minutes each, separated by an interval, produced a different result from a continuous exposure of 5 minutes' duration. The resulting diminution in mitosis was more marked when 80 minutes elapsed between the exposures than when the interval was 160 minutes. It was found that 24 exposures, each of 2½ minutes, separated by 80-minute intervals, produced a delayed lethal effect equivalent to that following a continuous irradiation of 4½ hours.

Another interesting paper, which does not admit of being summarised, is that of Moppett (*Proc. Roy. Soc.*, B. **110**, 1932) on the differential action of X-rays on tumour tissues.

Radiations affecting the living cells of a mammal have first to pass through the dead horny layer of the skin. It is the radiations which penetrate this layer that act upon the living cells beneath. Consequently Angus and Taylor (*Proc. Roy. Soc.*, B. **109**, 1931) have investigated the transmission of radiations through a sample of the horny layer of human skin. Measurements of the percentage transmission of visible and ultra-violet radiations between λ 5790 and λ 2300 are given.

We reported, not long ago, an important advance in our knowledge of respiration in insects contributed by Wigglesworth. It was shown, in the paper then referred to, that the extent of air in the tracheal capillaries of mosquito larvæ is determined by the osmotic pressure of the surrounding tissue fluids. The terminal regions of the tracheoles contain fluid when the animal is at rest, but during activity this fluid is removed in consequence of the increase in the osmotic pressure of the surrounding tissue fluids. This activity leads to the extension of air into the finest branches of the tracheal capillaries, with a consequent increase in the supply of oxygen to the active tissues. It was pointed out that the osmotic pressure of the tissue fluids of terrestrial insects may be far higher than in aquatic insects, and may be sufficient to draw the fluid into such fine tracheoles that a further increase due to muscular activity will have no further effect on them. Wigglesworth (*Proc. Roy. Soc.*, B. **109**, 1931) has

investigated this possibility in a number of terrestrial insects, and finds that the tracheal endings during rest do contain fluid which is removed during muscular activity. The fact that the fluid is not removed during prolonged fasting under dry conditions suggests that the osmotic pressure of the blood of these insects is maintained during life at an approximately constant level. Thus the mechanism regulating the extent of air in the tracheoles of aquatic insect larvæ is the same as that in terrestrial insects.

Another paper by Wigglesworth (*Q.J.M.S.*, **75**, 1932) deals with the function of the so-called " rectal glands " of insects. Observations on larval and adult insects belonging to all the main orders are described, and the literature on the subject is discussed. It is suggested that the rectal glands and rectal epithelium of insects play an important part in conservation of water by reabsorbing the water from excrement before it is discharged.

Thorpe (*Proc. Roy. Soc.*, B. **109**, 1932) has investigated the method by which an apneustic endoparasitic insect larva obtains its oxygen and eliminates carbon dioxide. The supposed respiratory function of the " tail " of Ichneumonid larvæ and of the " caudal vesicle " of Braconid larvæ was investigated in particular. Biological indications were employed for studying the oxygen absorption. The most useful was found to be pure cultures of the flagellate *Polytoma uvella*, as oxygen tension is the main factor controlling its movements. These organisms migrate to a region having a certain optimum oxygen tension, which is lower than that in water (saturated at atmospheric partial pressure). Consequently, when an insect larva is placed in a culture of these protozoans, they migrate to the surfaces of the larva, where the oxygen tension in the surrounding medium is being reduced. When the oxygen tension near these surfaces falls below the optimum they gradually move outwards. They thus provide a visible indication of the surfaces at which oxygen is being absorbed and of the rate of absorption. Pure cultures of the luminous bacterium, *B. phosphorescens*, were also employed for this purpose with success. The carbon-dioxide output was investigated by means of pH indicators. It was found by these means that the characteristic tail of Ichneumonid larvæ is of negligible importance as a respiratory organ. On the other hand, the caudal vesicle of Brachonid larvæ is respiratory in those forms where it is large and well supplied with blood, but the whole surface of the body is respiratory also, even in these forms. Even at its maximum development in *Apanteles* and *Microgaster*, the caudal vesicle can account, at most, for one-third of the total respiration.

There has been much division of opinion concerning the

factors which are responsible for the development of the broad summer and narrow winter rings of the scales of certain teleostean fish. The work of a number of authors suggests that seasonal variation in the food supply is the factor responsible, while Cutler (*Jour. Mar. Biol. Assoc.*, **11**, 1918) maintains that temperature, not food supply, is the controlling factor. In a recent paper, Bhatia (*Jour. Expt. Biol.*, **9**, 1932) describes a series of experiments, designed to clear up this point, in which both food and temperature were controlled. The Rainbow Trout (*Salmo irideus*) was selected as suitable material. It was found that the scales of trout fed uniformly, whether the temperature was normal, high, or low, do not exhibit periodic zones of broad and narrow rings. An abundant food supply at both high (17° C.) and low (4° C.) temperatures results in the formation of broad rings. Starvation at both high and low temperatures results in the formation of narrow rings. Alternating periods of abundant and deficient nutrition, irrespective of temperature, resulted in the production of corresponding alternating zones of broad and narrow rings. Variations in temperature had no direct effect on the production of periodic rings on the scales. It is suggested, however, that as at low temperatures the fish are less inclined to feed than at high temperatures, this may affect the amount of food consumed, and so indirectly affect the width of the rings formed.

ENTOMOLOGY. By H. F. Barnes, M.A., Ph.D., Rothamsted Experimental Station, Harpenden.

General Entomology.—Various books which have been published recently have been reviewed elsewhere. Others include the following: *Common Pests*, by R. W. Doane (viii + 398 pp., 215 figs. Springfield, Illinois: Charles C. Thomas; London: Baillière, Tindall, & Cox, 1931); *Handbook of the Insects and Other Invertebrates of Hawaiian Sugar Cane Fields*, by F. X. Williams (Experiment Station of the Hawaiian Sugar Planters' Assoc., 400 pp., Honolulu, 1931): this is a complete ecological survey of the smaller-sized fauna, including an introductory chapter by the late F. Muir on the theory and practice of parasite introduction; and *La Parthenogenese*, by A. Vandel (*Encyclopédie Scientifique* **7**, xix + 412 pp., Paris: G. Doin et Cie).

A Guide to the Study of the Wings of Insects with Suggestions for the Instructor (41 + 17 pp., 68 plates. Daw, Illston & Co., 1931) has been written by J. C. Bradley. The guide discusses the general characteristics of the wings and the venation in the orders and certain families. The plates are loose in an envelope, and the figures are printed faintly so that the student can ink in the veins. The booklet for the instructor consists of an explanation of the more difficult features of the wings illustrated.

R. E. Snodgrass has considered the general structure of the abdomen and its appendages in the first part of a study of the *morphology of the insect abdomen* (*Smithsonian Misc. Coll.*, **85**, No. 6, 1931, 128 pp.). It will be remembered that he has previously dealt with the morphology and evolution of the insect head and its appendages (*loc. cit.*, **81**, No. 3, 1928, 158 pp.), and also the insect thorax (*loc. cit.*, **80**, No. 1, 1927, 108 pp.).

A new book (*Die Forstinsekten Mitteleuropas ; ein Lehr- und Handbuch*, by K. Escherich. Band 3, Spezieller Teil, Abteilung 2 : *Lepidopteroidea : Die " Schnabelhafte " (Panorpatae) ; die " Kocherfliegen " (Trichoptera) ; die " Schmetterlinge " I (Lepidoptera I) ; Allgemeines, Kleinschmetterlinge, Spanner und Eulen*, xi + 825 pp. Berlin : Paul Parey, 1931, 57 gold marks) deals with studies whose object is to find out the causes underlying the phenomenon of the fluctuations in the numbers of an insect, which cause it to be a pest one year while attracting no attention in another year. The title is misleading. In a useful paper on the ecology of populations (*Qtly. Rev. Biol.*, **7**, 1932, 27–46), G. F. Gause has shown that (1) the correlation between the density of population of very different organisms and ecological factors in natural conditions can be expressed by means of a special type of curve, and (2) there exists a close connection between the ecological plasticity of a species and the population of its average conditions on the ecological scale. The experimental study of the influence of temperature on the density of saturating populations of different organisms has shown that temperature influences the density of such populations.

V. E. Shelford (*Illinois Dept. of Registration and Education*, **19**, 1932, 487–547) has made a detailed experimental and observational study of the chinch bug in relation to climate and weather. This paper includes a study of the records of abundance, migration, rise, and decline of the pest in Illinois since 1840. In the early history of the outbreaks there was a striking correlation between human death-rate and chinch-bug damage. With better-developed agriculture and improved sanitary conditions this relation has become less marked. Various types of quantitative methods used in the study of numbers of terrestrial animals, including insects, are discussed by J. F. V. Phillips (*Ecology*, **12**, 1931, 633–49). D. M. DeLong (*Ann. Ent. Soc. Amer.*, **25**, 1932, 13–17) points out the difficulties encountered in the estimation of insect populations by the sweeping method. There is a long summary in English to a paper by A. A. Lubischew on the methods of estimating losses caused by two insects pests, *Cephus pygmæus* L. and *Harmolita noxiale* Portsch. (*Bull. Plant Protection*, **1**, No. 2, undated, 360–505).

In a study of the influence of atmospheric humidity on the thermal death point in insects (*Jl. Expt. Biol.*, **9**, 1932, 222–31), K. Mellanby describes a technique suitable for exposing small insects to high temperature and air of controlled humidity. Two main causes of death in insects when killed at high temperatures were deducted: (1) when the temperature is over 40° C., they die from the effects of heat, and (2) below 36° C., all the insects used were able to survive at least twenty-four hours in moist air, but in dry air, insects which are unable to conserve their water may die of desiccation. In hot air, over 40° C., certain large insects are better able to survive in dry air, as they keep their bodies cool by evaporating water.

Three important papers on the physiology of excretion in *Rhodnius prolixus*, dealing with: I, "The Composition of the Urine"; II, "The Anatomy and Histology of the Excretory System"; and III, "The Mechanism of Uric Acid Excretion," have appeared by V. B. Wigglesworth (*Jl. Expt. Biol.*, **8**, 1931, 411–27, 428–42, and 443–51). These papers have already been discussed in "Recent Advances in Zoology" in the January number. In the last paper it has been shown that a definite circulation of water takes place through the excretory system. Much of the readsorption was seen to take place in the lower segments of the Malpighian tubes, but in addition probably some takes place in the rectum. It was suggested that the readsorption of water might prove to be the function of the so-called "rectal glands." In another paper (*Q.J.M.S.*, **75**, 1932, 131–50) the same author has examined this hypothesis. As a result he suggests that the rectal glands and rectal epithelium of insects readsorb water from the excrement before it is discharged, and thus play an important part in water-conservation. Observations on larval and adult insects belonging to all the main orders are described in support of this theory. V. B. Wigglesworth, in a further paper (*Proc. Roy. Soc. London*, **109 B**, 1931, 354–9) on the extent of air in the tracheoles of some terrestrial insects, shows that during rest the tracheal endings contain fluid. During muscular contraction (*e.g.* as a result of asphyxiation) this fluid is removed, probably by the increased osmotic pressure. The fluid, however, is not removed during prolonged fasting under dry conditions (in the flea and meal-worm). This suggests that the osmotic pressure of the blood of these insects is maintained during life at a more or less constant level.

An exceedingly interesting subject has received the attention of W. L. McAtee in the form of a recent publication (*Smithsonian Misc. Coll.*, **85**, No. 7, 1932, 201 pp.). It is entitled "The Effectiveness in Nature of the So-called Protective Adaptations in the Animal Kingdom, chiefly as illustrated by

the Food Habits of Nearctic Birds." A considerable part of this volume deals with insects.

Three additional parts of the *Catalogue of Indian Insects* have recently come to hand, namely: Part 20—"Alucitidæ (Pterophoridæ)," by T. Bainbrigge Fletcher (1931, 61 pp.); Part 21—"Lycidæ," by R. Kleine (1931, 52 pp.); and Part 22—"Phaloniadæ and Chlidanotidæ," by T. Bainbrigge Fletcher (1931, 15 pp.).

Some notes on insects inhabiting the saline waters of the Californian desert regions have been made by W. H. Thorpe (*Pan-Pacific Ent.*, **7**, 1931, 145–53). J. C. Hamlin (*Ann. Ent. Soc. Amer.*, **25**, 1932, 89–120) has conducted an investigation into the stability and restriction of feeding habits of certain cactus insects. J. W. Wilson (*Jl. N.Y. Ent. Soc.*, **40**, 1932, 77–93) has compiled a list of Coleoptera and Diptera collected from a New Jersey sheep pasture. Two useful bulletins which deal with mushroom insects have been published recently: *Mushroom Insects: Biology and Control*, by C. A. Thomas (*Penn. Expt. Sta.*, Bull. 270, 1931, 42 pp.), and *Mushroom Growing* (*Min. Agric.*, Bull. 24, 1931, 26 pp.). The occurrence of insects at sea is the subject of a paper by J. J. Walker (*Ent. Mon. Mag.*, **67**, 1931, 211–32, 254–68).

Some methods of rearing and maintaining large stocks of fleas and mosquitoes for experimental purposes are described by H. S. Leeson (*Bull. Ent. Res.*, **23**, 1932, 25–31). A valuable study of the temperature and humidity in various types of insect-rearing cages has been made by R. C. Smith (*Jl. Agric. Res.*, **43**, 1931, 547–57).

Orthoptera.—E. M. Walker has started a series of papers on the anatomy of the primitive Orthopteran, *Grylloblatta campodeiformis* Walk. In the first contribution (*Ann. Ent. Soc. Amer.*, **24**, 1931, 519–36) the exoskeleton and musculature of the head is described. The second part of T. Shiraki's papers on the Orthoptera of the Japanese Empire (*Insecta Matsumurana*, **5**, 1931, 171–209) deals with the Blattidæ. In the first part (*loc. cit.*, **4**, 1930, 181–252) the Gryllotalpidæ and Gryllidæ were considered.

The external morphology of grasshopper embryos of known age and with a known temperature history have been studied and figured by Eleanor H. Slifer (*Jl. Morph.*, **53**, 1932, 1–22). E. R. McGovran (*Ann. Ent. Soc. Amer.*, **24**, 1931, 751–61) has devised a method of measuring the tracheal ventilation of grasshoppers, and has given some of his results.

Coleoptera.—N. H. Joy has written *A Practical Handbook of British Beetles* (vol. I, xxvii + 622 pp.; vol. II, 170 plates (pp. 1–170) and index (pp. 171–94) London: Witherby, 1932). The objects of the book are to help the beginner to

identify his captures, and to bring together all the information respecting the distinctive characters of the species added to the British list since Fowler's work. The outline figures, of which there are 2,040, will be of great use to collectors.

A systematic catalogue of Formosan Coleoptera by Y. Miwa in English has been published separately as Contribution No. 32, *Ent. Lab. Taihoku Imp. Univ.* (1931, 359 pp.) (reprinted from *Dept. Agric. Govt. Res. Instit., Taihoku, Formosa, Rept. No.* 55).

A few years ago there appeared a paper on "Tropisms and Sense Organs of Lepidoptera" (*Smithsonian Misc. Coll.*, **81**, No. 10, 1929, 1–59), by N. E. McIndoo. The same author has now followed this up with a complementary paper on "Tropisms and Sense Organs of Coleoptera" (*loc. cit.*, **82**, No. 18, 1931, 1–70). The information available on the subject is reviewed, and new experimental and other evidence is brought forward, using the Mexican bean beetle as a representative type.

An important paper (*Q.J.M.S.*, **75**, 1932, 49–129) on the structure and development of the reproductive system in the Coleoptera, with notes on its homologies, by Margot E. Metcalfe has recently appeared. Some attempt has been made to compare her conclusions with those of other workers, and so reduce the number of terms used in such work.

The morphology of the head-capsule of some Coleopterous larvæ is discussed and illustrated in a paper by W. E. Whitehead (*Canad. Jl. Res.*, **6**, 1932, 227–52). The egg and external structure of the larva of *Atomaria linearis* Stephens (Cryptophagidæ), the Pigmy Mangold beetle, have been described for the first time by H. C. F. Newton (*Ann. Appl. Biol.*, **19**, 1932, 87–97). The first part of an interesting paper on the distasteful character, warning coloration, and enemies of Coccinellids, by F. Heikertinger, has appeared (*Biol. Zentralb.*, **52**, 1932, 65–102). The fifth paper, on the Elateridæ of Formosa by Y. Miwa, has now appeared (*Trans. Nat. Hist. Soc. Formosa*, **21**, 1931, 72–98).

In a brief note (*Ent. News*, **43**, 1932, 6–7), Nellie M. Payne gives some figures to show that pupæ of the mealworm exposed to alternating temperatures generally developed somewhat faster than would be predicted from their development at constant temperatures. The effect of high and low temperatures on the brood stages of the western pine beetle, ***Dendroctonus brevicornis*** Lec., has received the attention of J. M. Miller (*Jl. Agric. Res.*, **43**, 1931, 303–21).

A further contribution to the knowledge of the immature stages of some Japanese Cerambycid beetles has been made by T. Kojima (*Tokyo Jl. Coll. Agric.*, **11**, 1931, 263–308).

J. S. Huxley has made a study of the relative growth of

mandibles in stag-beetles (*Jl. Linn. Soc., Zoo.*, **37**, 1931, 675–703). As a result of certain facts discovered, it is concluded that the "forms" of male Lucanids distinguished by coleopterists are purely growth-forms, and have no systematic significance. The chief ways of handling data for heterogonic organs in holometabolous insects are discussed. D. Ludwig (*Jl. Expt. Zool.*, **60**, 1931, 309–23) deals with weight and metabolism changes in the Japanese beetle (*Popillia japonica* Newman).

The insect food of young rooks has been studied by A. Chappellier (*Ann. Epiphyties*, **16** (1930), 1931, 209–18), who finds the species most frequently eaten are *Melolontha melolontha* L. (*vulgaris* F.), *Amphimallus majalis* Razoum (*Rhizotrogus rufescens* Latr.), and *Otiorrhynchus ligustici* L.

C. L. Fluke, L. F. Graber, and K. Koch (*Ecology*, **13**, 1932, 43–50) have shown that under field conditions any factor or group of factors of the internal and external environments, limiting the amount of subterranean growth and the regenerative capacity of the grass, intensifies the degree of injury due to the grubs of *Phyllophaga* spp. In addition a generally favourable environment for the grass reduces the infestations of the insect. This follows a paper by Graber, Fluke, and S. T. Dexter (*loc. cit.*, **12**, 1931, 547–66), which showed that the same held good in controlled cultures of *Poa pratensis*.

Lepidoptera.—The butterflies of the district of Columbia and its vicinity are the subject of a bulletin by A. H. Clark (*Smithsonian Instit. U.S. Nat. Mus.*, Bull. 157, 1932, 337 pp.).

Hemiptera.—A paper by E. Rivnay (*Parasitology*, **24**, 1932, 121–36) attempts to determine: (*a*) what stimuli attract the bed bug (*Cimex lectularius* L.), and how this insect locates its prey; (*b*) why the bug discriminates between individual persons when it readily feeds upon animals other than man; and (*c*) what the factors are which underlie some of the bug's habits.

G. E. Hutchinson (*Amer. Nat.*, **65**, 1931, 573–4) has recorded *Trichocorixa* as occurring in salt water, and mentions its zoogeographical significance.

F. F. Smith and F. W. Poos (*Jl. Agric. Res.*, **43**, 1931, 267–85) have made a study of the feeding habits of some leaf-hoppers of the genus *Empoasca*. The biology of *Erythroneura pallidifrons* Edw. has been studied by Elsie I. MacGill (*Bull. Ent. Res.*, **23**, 1932, 33–44). This Jassid is the common leaf-hopper of glass houses in this country, and was reared on cotton as the host-plant. A Mymarid parasite was reared; previous records of Mymarid parasites attacking this insect came from Sweden and the United States.

The internal anatomy of the male lac insect, *Laccifer lacca* Kerr, has now been worked out in detail by A. B. Misra (*Proc.

Zool. Soc. London 1931, 1931, 1359–81). This follows a paper by the same author on the female lac insect which was mentioned in the January issue.

Hymenoptera.—After studying growth in the larvæ of some Tenthredinidæ (*Jl. Expt. Biol.*, **8**, 1931, 355–64), H. W. Miles has shown that growth does not follow a regular geometrical progression throughout the larval life in this group. So Dyar's law for growth in the larvæ of *Lepidoptera* has only a limited application to growth in Tenthredinid larvæ. However, it can be used satisfactorily to check the number of ecdyses during that part of the larval life directly associated with feeding and increase in size. R. L. Taylor (*Ann. Ent. Soc. Amer.*, **24**, 1931, 451–66) has made a similar study on the instars of *Phyllotoma nemorata* Fallen. He also finds that in the last larval instar the head capsule does not show the usual increase in size. In addition, he shows that in the first four instars the head widths tend to merge at their extremes owing to the extent of individual variation. H. W. Miles (*Bull. Ent. Res.*, **23**, 1932, 1–16) has also made some biological studies of sawflies infesting *Ribes*. He deals with *Pteronidea ribesii* Scop., *P. leucotrochus* Hartig, and *Pristiphora pallipes* Lep. The first part of a paper on the morphology, anatomy, and biology of *Lophyrus pini* L. by G. Eliescu has appeared (*Zeits. f. angew. Ent.*, **19**, 1932, 22–67).

In a paper on respiration in the larvæ of parasitic Hymenoptera (*Proc. Roy. Soc. London*, **109 B**, 1932, 450–71), W. H. Thorpe gives details of using biological indicators for studying the oxygen absorption. It is concluded that the "tail," a feature of many first instar Ichneumonids, is of no importance for respiration. With regard to the caudal vesicle of Braconids, there are considerable differences in structure in different genera. Where the vesicle is large, and supplied with a good blood circulation, it is of undoubted importance as a respiratory organ. However, gas exchange takes place over the whole body surface. In *Apanteles* and *Microgaster*, on the other hand, the vesicle, at its maximum development, cannot be responsible for more than about one-third of the total respiration. In other forms, *e.g.* *Orgilus*, its respiratory function is even less.

An important paper by G. Salt on the parasites of the wheat stem sawfly, *Cephus pygmæus* Linn., in England has appeared (*Bull. Ent. Res.*, **22**, 1931, 479–546). Thirteen species, of which nine are primary and four are hyperparasites, are to be found in this country, and they are all dealt with in considerable detail. This is followed (*loc. cit.*, 547–50) by a short note by C. W. Smith on the colonisation in Canada of *Collyria calcitrator*, one of the parasites previously studied. Apparently this

species attacked *Cephus*, and reached the second larval stage successfully in its new home. Certain details of the morphology and life-history of *Heterospilus cephi* Rohwer, another parasite of the wheat stem sawfly, have been given by C. C. Hill and H. D. Smith (*Jl. Agric. Res.*, **43**, 1931, 597–609).

The primary larvæ of three Ophionine Ichneumonids parasitic on *Rhyacionia buoliana* Schiff., have been described by W. H. Thorpe (*Parasitology*, **24**, 1932, 107–110). The life-history and general behaviour of *Monodontomerus aereus* Walker, which is both a primary and secondary parasite of the Brown-tail moth and Gipsy moth, form the subject of a paper by C. F. W. Muesebeck (*Jl. Agric. Res.*, **43**, 1931, 445–60).

The importance of temperature as a factor in the activity and development of the Chinese strain of *Tiphia popilliavora*, a parasite of the Japanese beetle, has been demonstrated by J. K. Hollaway (*Jl. N. Y. Ent. Soc.*, **39**, 1931, 555–63).

There is a note on *Lælius anthrenivorus* Trani, an interesting Bethylid parasite of *Anthrenus verbasci* L., in France by A. M. Vance and H. L. Parker (*Proc. Ent. Soc. Wash.*, **34**, 1932, 1–7). This species is ectoparasitic in the larval stage on certain of the Dermestidæ that infest museum specimens. Other species of *Lælius* have previously been found in the U.S.A., France, and Italy, from which last-named country *L. anthrenivorus* was first recorded.

In a paper (*Q.J.M.S.*, **74**, 1931, 647–68) on the " olfactory pores " in the honey bee, H. C. F. Newton has described their structure and development in the pupæ, but finds no evidence supporting McIndoo's theory that the actual termination of the nerve fibres is exposed to the outside air.

Diptera.—The terminal segments of two species belonging to the genera *Psychoda* and *Telmatoscopus* and three species of the genus *Phlebotomus* are the subject of a comparative study by S. Mukerji (*Ind. Jl. Med. Res.*, **19**, 1931, 433–46).

The larvæ and pupæ of *Ficalbia* (*Minomyia*) *hybrida* Leicester have now been shown by J. Bonne-Wepster (*Bull. Ent. Res.*, **23**, 1932, 69–72) to get their oxygen from aquatic plants. Previously only *Tæniorhynchus* larvæ have been recorded as having this mode of obtaining oxygen.

An important paper, entitled " Resistance of Varieties of Winter Wheat to Hessian Fly " (*Kansas Agric. Expt. Sta.*, Tech. Bull. 27, 1931, 58 pp.), by R. H. Painter, S. C. Salmon, and J. H. Parker has appeared. Among other results, detailed information is given concerning the evidence for the presence of distinct biological strains or populations of Hessian fly, the one in the hard-wheat belt of Kansas and the other in the soft-wheat area in the same State. Two papers have been written on gall midges injurious to grasses : one by W. Tomaszewski

(*Arbeit. a. d. Biolog. Reich. f. Land- und Forstwirt.*, **19**, 1931, 1–15), which deals both with midges affecting the flower heads and the stems ; the other by H. F. Barnes (*Bull. Ent. Res.*, **22**, 1931, 199–203), which is restricted to those preventing seed formation.

A good account of British Tabanidæ has been provided by E. R. Goffe (*Trans. Ent. Soc. South of England 1930*, 1931, 43–114), particular attention being paid to variation. In the same periodical (*loc. cit.*, 1931, 1–42) B. M. Hobby has compiled a useful list of the British species of Asilidæ and their prey.

Several methods of general biological application are used and explained in a bulletin on the biology and control of the blueberry Maggot by F. H. Lathrop and C. B. Nickels (*U.S.D.A.*, Tech. Bull. 275, 1932, 76 pp.). K. Koidsumi (Contribution No. 30, *Ent. Lab. Taihoku Imp. Univ.*, 1931, 68 pp. ; reprint from *Bull. Dept. Agric.*, *Govt. Res. Instit.*, *Taihoku*, No. 85) deals with the fatal action of low temperatures upon the pupæ and larvæ of the Melon-fly (*Chætodacus cucurbitæ* Coq.). There is a résumé in English. The alimentary canal of the apple maggot, *Rhagoletis pomonella* Walsh, has been studied by R. W. Dean (*Ann. Ent. Soc. Amer.*, **25**, 1932, 210–23). Usually scatophagous forms of Dipterous larvæ and those of medical importance have attracted attention in this line of work, so that this paper is welcome.

In a second paper on *Tylenchinema oscinellæ* Goodey 1930, a nematode parasite of the Frit-fly, T. Goodey (*Jl. Helminth.*, **9**, 1931, 157–74) has shown that the site of entry into the gut of the host of those larvæ making their way to the exterior is the wall of the food reservoir.

R. W. Wells (*Jl. Econ. Ent.*, **24**, 1931, 1242–7) has shown that there are distinct possibilities in the use of electrified traps for the destruction of houseflies and blowflies. Such traps might be of importance if used round dairies, farm buildings, etc. *U.S.D.A.*, Tech. Bull. 270 (1931, 10 pp.), by E. W. Laake, D. C. Parman, E. C. Bishopp, and R. C. Roarck, deals with the chemotropic responses of the housefly, greenbottle flies, and the black blowfly. R. P. Hobson (*Jl. Expt. Biol.*, **9**, 1932, 128–38), in a study of the rôle of the intestinal flora in digestion in blowfly larvæ, comes to the conclusion that micro-organisms play no part in intestinal digestion.

R. W. Burrell (*Jl. Agric. Res.*, **43**, 1931, 323–36) has described the method of shipment, manipulation at the insectary, colonisation, and biology of *Dexia ventralis*, a Tachinid parasite of the Japanese beetle, which is being imported from Chosen (*Korea*) into the United States of America.

G. R. Coatney (*Parasitology*, **23**, 1931, 525–32) deals with certain aspects of the biology of *Pseudolynchia maura* Bigot,

the Hippoboscid parasite of pigeons. The effect of feeding it under laboratory conditions on pigeons (normal wild host) and chickens, mourning dove and man (more or less unsuitable hosts) is noted.

E. C. Alfonsus and E. Braun have made a preliminary study of the internal structures of *Braula cœca* Nitzsch (*Ann. Ent. Soc. Amer.*, **24**, 1931, 561–82).

Other Orders.—D. S. Maclagan (*Bull. Ent. Res.*, **23**, 1932, 101–45) has made a thorough ecological study of *Smynthurus viridis* L. Considerable additions have been made to the knowledge of the life-history and bionomics. The latter has been dealt with in two sections, dealing with biotic and physical environmental factors, respectively. The part played by such factors in limiting the normal increase has been determined.

In a further (7th) contribution towards a knowledge of the biology of Thysanoptera with reference to the cotton plant, Elsie I. MacGill (*Ann. Appl. Biol.*, **18**, 1931, 574–83) has studied the relation between temperature and humidity and the life-cycle. Apparently the degree of relative humidity has little or no effect on the length of life-cycle of *T. tabaci*, although it has a marked effect on the mortality of the immature stages.

A method of separating the dorsal and ventral surfaces of the wings in mayflies, which will be useful in studying wing venation, is described by H. T. Spieth (*Ent. News*, **43**, 1932, 103–5). J. S. Phillips (*Trans. Ent. Soc. London*, **79**, 1931, 399–426) has made an important study of the New Zealand mayfly nymphs.

L. R. Setty (*Ann. Ent. Soc. Amer.*, **24**, 1931, 467–84), in a paper on the biology of *Bittacus stigmaterus* Say, has described the pupa; this apparently is the first time a pupa belonging to this genus has been described.

ARTICLES

SOME RECENT RESEARCHES IN SOUND

BY PROF. E. N. da C. ANDRADE

Quain Professor of Physics in the University of London

AMONG the classical experiments of sound, described in every textbook, must be numbered Chladni's figures on vibrating plates, Kundt's dust figures in a tube containing a vibrating column of air and the sensitive flame. The beauty of the phenomena, and the ease with which they can be produced, have rendered them such popular subjects for demonstration that they are familiar to every student who has taken a course in elementary physics; yet in spite of the fact that they have been the subject of investigation by many distinguished workers, including men no less than Tyndall and the late Lord Rayleigh, the various processes by which the results are produced have remained obscure. Investigations recently carried out in the writer's laboratory [1] have thrown light on many aspects of these experiments, and, while in the case of the sensitive flame there is still much to be done, it is now possible to give some account of the way in which the various observed appearances are brought about. The advance has been made possible by the fact that the new technique of thermionic valve oscillators gives us what was denied to the older researchers, namely, an easy method of producing a note of any desired pitch which can be maintained as long as is desired at constant frequency and of a controlled intensity. Had this been available earlier there is little doubt that the results here described would have been obtained long ago.

The problem offered by the sand figures, first produced by Chladni on a vibrating plate, is a comparatively simple one, namely, why do the sand particles move to the nodal lines?

[1] E. N. da C. Andrade. "On the Circulations Caused by the Vibrations of Air in a Tube," *Proc. Roy. Soc.*, A **134**, 445, 1931.

E. N. da C. Andrade. "On the Groupings and General Behaviour of Solid Particles under the Influence of Air Vibrations in Tubes," *Phil. Trans. Roy. Soc.*, A **230**, 413, 1932.

E. N. da C. Andrade. "Absolute Measurement of Sound-Amplitudes and Intensities," *Phys. Soc. Discussion on Audition*, June 1931.

E. N. da C. Andrade and D. H. Smith. "The Method of Formation of Sand Figures on a Vibrating Plate," *Proc. Phys. Soc.*, **43**, 405, 1931.

G. B. Brown. "On Sensitive Flames," *Phil. Mag.*, **13**, 161, 1932.

Apparently it is always taken as a matter of obvious necessity, yet the only explicit account of the machinery of motion of the particles which I have been able to trace, namely, that given in Winkelmann's celebrated *Handbuch* (vol. ii, p. 385, 1909) is incomplete, and erroneous as far as it goes. The mechanism which suggested itself to me, and which was confirmed by experiments carried out in conjunction with Mr. D. H. Smith, is as follows. Let us consider a complete vibration of the plate, starting at the instant of downward motion through the equilibrium position, when the velocity is greatest. During the motion down to the lowest position the velocity continually decreases and the acceleration is upwards, so that the reaction between the plate and a grain of sand is greater than the reaction when the plate is at rest. As the plate moves upwards to the equilibrium position the acceleration is likewise upward, but during the remainder of the upward motion the velocity is diminishing and the acceleration is downwards, so that the reaction is less than normal. If, before the plate reaches its highest position, the downward acceleration at the spot considered reaches the value g, the particle will cease to be in contact with the plate, and will move away from it with an initial velocity equal to that of the plate at this spot and at this instant, and with a small component towards the node, owing to the convexity of the plate upwards. If we neglect any possible effect of the air the particle will describe a parabola and fall back on to the plate.

Its subsequent behaviour will be determined by the position and motion of the plate at the spot on which it falls. If it strikes the plate when it is moving upwards and convex upwards the particle will be thrown outward to a nodal line, but if it strikes the plate when it is concave upwards it may clearly be thrown in towards the place of greatest motion. This is more likely to happen when the particle is thrown vigorously upwards, so that it is some time in the air. The point has been subjected to a brief mathematical discussion, from which the conditions for a motion away from the nodes can be approximately deduced.

If this picture is correct the grains of sand should not travel right up to the nodal line, but to a line at all points of which the greatest acceleration of the plate is g. To confirm this a steel plate was maintained in vibration by a magnet fed with current of controlled frequency and intensity from a valve oscillator. Since every part of the plate moves up and down with a simple harmonic motion, the greatest acceleration at any point on the edge can be at once calculated if the amplitude at that point is measured with a microscope, the frequency being known. It was found that while, when the vibration was

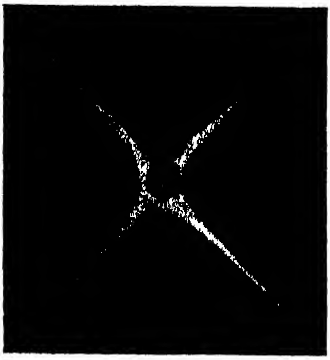


FIG 1.

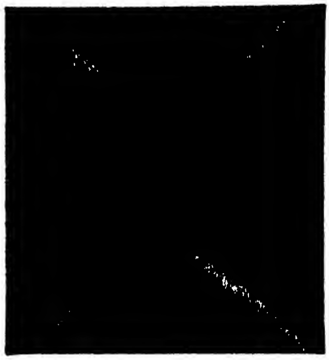


FIG. 2

FIG. 3

FIG. 4.

PLATE I.

Figs. 1 2 by permission from *The Proceedings of the Physical Society.*
Figs. 3–5 by permission from *The Proceedings of the Royal Society.*
Figs. 6–11 by permission from *The Transactions of the Royal Society.*

vigorous, the sand grains cleared from a space whose boundary lay close to the nodal line, when the vibration was less energetic the grains cleared from a very limited region only, no matter how long the plate was maintained in motion. Fig. 1, Plate I, shows the equilibrium state for a vigorous vibration, Fig. 2 for a moderate vibration.

Measurements made on this plate showed that the acceleration was rather greater than g on the boundary line of the sand. It was found that sand grains tended to stick to the steel, while fragments of crushed glass moved more freely. To obtain a more accurate check, measurements were then made with such fragments on a vibrating steel bar, of which the frequency was lower and consequently the amplitude corresponding to g larger, permitting more precise measurements. The average value found for the maximum acceleration at the boundary line of the group of particles was 978 cm/sec^2, which is astonishingly close to the true value of g, viz. 981 cm/sec^2.

Another point in which the theory is confirmed is illustrated by the photographs. According to the calculation, when the vibration is vigorous there is a good chance of a particle striking the plate when it is concave upwards, and being thrown towards the antinode. It will be seen that while at the low intensities, represented by Fig. 2, the antinodal regions are quite clear of particles, at the high intensity of Fig. 1 there are a few particles distributed all over the plate. This is, of course, clearer in the original photographs than in the reproductions. It may be added that the hitherto unconfirmed statement that the light powder lycopodium, which Faraday showed to move to the antinodes in consequence of the turbulent motion of the air, would move to the nodes in a vacuum has been verified by putting the electrically maintained plate in an exhausted vessel.

The problems attaching to Kundt's tube are of a more complicated character. Kundt himself described their essential features, which vary with the density of the powder and the position of the driving disk, carried by the stroked rod, relative to the nodes formed in the air in the tube. It may be said at once that the work to be described has shown that the determining condition is the energy of the air vibration : when a node is near the driving disk the vibration is very vigorous, while when a loop is near the driving disk it is comparatively mild.[1]

[1] This fact, which can be proved at once by an elementary mathematical discussion, appears to some paradoxical. A simple analogy will suffice, perhaps, to clear up any difficulty. Let one end of a cord be firmly attached to a support, and the other end be held between the fingers and shaken. If the frequency of shaking be a resonant frequency of the cord a very small motion of the fingers produces a large motion at the loop ; if the frequency be adjusted so that the fingers are near a loop the general motion will be comparatively small.

With a node near the driving disk and a light powder, lycopodium, the dust collects in heaps at the nodes, and there are no other patterns in the tube. With an antinode near the driving disk the light powder forms a figure which I call an "eye," and which Kundt called a "hole," round each node. Such an eye, with two curved walls of dust formed symmetrically about the node, is shown in Fig. 8, Plate III. With heavier powders, such as fine sand, and a node near the driving disk, dust heaps or eyes form about the nodes, between which a series of sharp ridges appear, as illustrated in Fig. 7, Plate II, and Fig. 10, Plate III. With an antinode near the driving disk there is no movement. Interpreted in the light of the recent experiments this means that with vigorous vibration and inert particles ridges are formed between the nodes; with less vigorous vibration and much lighter particles eyes are formed about the nodes, while with vigorous vibration and light particles heaps are formed at the nodes, which are merely limiting cases of the eyes, when the two sides are moved up to the node so that they blend.

The behaviour of particles in a vibrating fluid depends upon a number of factors, including the radius of the particle, the relative densities of the substance of the particle and of the fluid, the kinematic viscosity of the fluid, and the frequency of the vibration. To consider two extreme cases: if the particle is comparatively large and fairly dense, and the vibration is rapid, the particle remains at rest, and the fluid washes to and fro over it; if the particle is very small and light, and the frequency of vibration not too high, the particle moves to and fro with the full amplitude of the fluid. Calculation shows that with such dust particles as are used in Kundt's tube, *e.g.* cork particles, with air as the medium and very low frequency, say 100 vibrations a second or less, the second case is nearly realised, while with smoke particles, the radius of which is about 5×10^{-5} cm., it is realised very closely even when the frequency is as high as 2,000 vibrations a second, the amplitude of the smoke particles being within 1 part in 1,000 of that of the air, while for lower frequencies the departure is less. Smoke particles, therefore, can be used as indicating points, following closely and making visible the motion of the air. On the other hand, when the frequency is as high as 850 or so, small cork particles move with only half the amplitude of the air motion, and at higher frequencies, such as are usually employed, move still less, tending to realise the conditions of the first case. It may be taken, then, that for the particles and the frequencies generally utilised in the tube experiment the particles act as obstacles over which the air washes to and fro.

In my experiments the source of sound was a loud-speaker

FIG. 5.

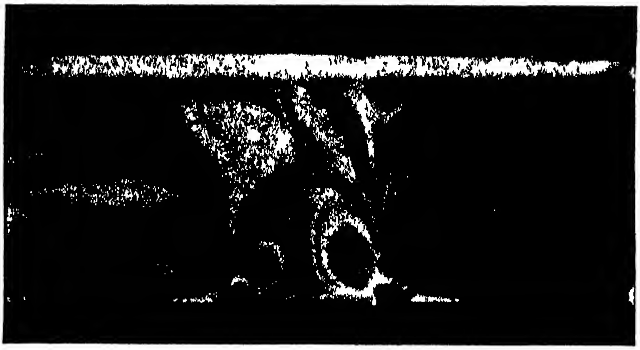


FIG. 6

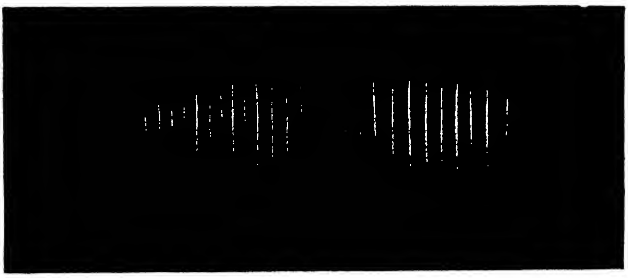


FIG 7

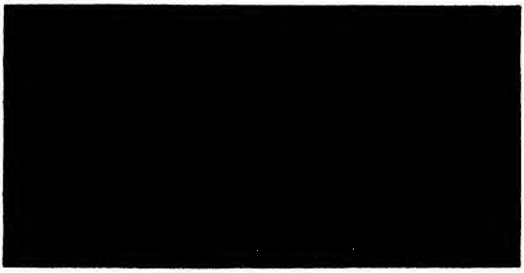


FIG 9

PLATE II.

unit, mounted so that the diaphragm, which could move freely, closed one end of the tube, usually about 3·5 cm. in diameter. The unit was fed with current from a valve oscillator, with filter and two-stage amplifier, which gave a note of good intensity over the range 2,500 to 50 vibrations a second. The wave form was observed with a cathode-ray oscillograph, and was found to be a pure sine wave when the amplitude was not too large. The length of the tube was kept constant, and the frequency varied at will. To observe the vortices about to be described a glass box of rectangular cross section was mounted in the middle of the tube, the transition from circular cross section to rectangular form being made smoothly by suitably shaped metal pieces, so that the whole formed one tube without discontinuities. For illumination a flat beam of intense blue-violet light was used, by means of which any section of the tube could be isolated for observation. Convection was avoided by a careful system of water-jacketing.

To observe the behaviour of the air about an obstacle a cylinder was fixed across the rectangular box, and a little cigarette smoke introduced to render the motion visible. With the cylinder at an antinode it was found that as soon as the intensity of vibration exceeded a certain value a beautiful vortex system was formed about the obstacle, the form of which is well illustrated in Fig. 3, Plate I. The air vibration is in a line parallel to the top of the page : the direction of motion in the vortex is outward from the obstacle in this direction, and inward toward the obstacle at points above and below it in the photograph. The stronger the vibration the larger the vortex system. The general appearance of the vortex system about a sphere is very similar for a median cross section, but the lines of flow in this case are, of course, identical in all planes through the line passing through the centre of the sphere and parallel to the vibration vector.

Lord Rayleigh many years ago calculated that in a tube full of a real, *i.e.* viscous, gas in vibration there should be a slow general circulation between node and antinode, the air passing along the wall of the tube from antinode to node, and back up the centre. Such a circulation had never been observed experimentally, although some remarks of Dvorak dealing with a dust phenomenon were interpreted to mean that something of the kind had been seen. Experience shows that the circulation requires very steady and carefully controlled conditions to produce it, and it could certainly not be made to appear with the old technique. With a tube carefully water-jacketed and a maintained note of suitable frequency and intensity the circulation was made to reveal itself by the motion of smoke. Fig. 4, Plate I, shows one section of the node to

antinode circulation, Fig. 5, Plate II, two sections, separated by an antinode. The light isolates a central section of the tube: the whole circulation is reproduced by rotating the picture about the axial line of the tube.

Such a general circulation will, of course, interfere with the formation of a symmetrical vortex about an obstacle. When, however, the vibration is not too vigorous the general circulation is so sluggish that the vortex is not disturbed appreciably, as can be seen by the symmetry of the pattern shown in Fig. 3. As, however, the intensity of the vibration is increased, the vigour of the general circulation gains on that of the vortex motion, which finally is almost completely overcome. This fact is very important for the explanation of the dust phenomena.

Before proceeding to the discussion of the dust figures one more feature connected with the smoke may be mentioned. Observation through a microscope shows the individual smoke particles as bright points, which are drawn out into lines when the air is thrown into vibration. As the smoke takes up the full amplitude of the air motion measurement of the length of these lines enables us to find the absolute intensity of the sound. This measurement requires a little practice, but a simple technique has been evolved which gives fair accuracy. This measurement of the traces of smoke particles thus provides an absolute method of finding the intensity of the sound. The wave form being observed with a cathode-ray oscillograph we are dealing in these experiments with a vibration of known frequency, amplitude, and wave form.

The formation of dust ridges was explained many years ago by W. König on the basis of hydrodynamic forces set up by the vibrations of a perfect fluid. Such a fluid washing periodically over two spheres can be shown to give rise to a repulsion, falling off very rapidly with the distance, if the centres of the spheres are in the line of vibration, and an attraction if they are in the transverse position. It was argued that if a series of ridges is formed the mutual repulsions will keep them in position, but it is hard to see how they are originally brought into existence on this theory. Certain observations show the theory to be inadequate in any case. Occasionally two isolated ridges can be seen to form, especially near a node, and it is difficult to explain this in terms of repulsions alone. Again, no ridges whatever are formed until the intensity exceeds a certain value, when they suddenly appear at the antinode, further increase in intensity leading to an extension of the ridge system towards the nodes. The calculated repulsions increase smoothly as the amplitude increases, so that they offer no reason for a sudden appearance of ridges.

To test the point definitely small spheres were made of pith, and a ridge of such spheres cemented across the tube. It was then found that, provided the vibration exceeded a certain intensity, a single ridge of loose spheres would form up parallel to the fixed ridge, approaching the fixed ridge if the spheres were initially too far away, and receding from it if they were too close. In other words, there is a definite equilibrium position with two ridges only, quite independent of any further ridges, which definitely establishes the inadequacy of König's theory.

It is a feature of a viscous fluid that vortex motion sets in only when a certain velocity is definitely exceeded, so that the sudden appearance of ridges as intensity is increased suggests vortex motion, and not the irrotational motion calculated by König, as the origin of the ridges. The type of vortex discovered to exist round an obstacle seemed likely to furnish the necessary forces. In the case of the ridges the obstacles lie on the bottom of the tube, so that the effect of two obstacles, cylinders, resting against one side of the rectangular tube was tried. It was soon found that if the intensity and frequency were suitable the vortex systems due to the two obstacles just touched, as shown in Fig. 6, Plate II. Each system is, incidentally, half that caused by an obstacle in the middle of the tube (Fig. 3), as is to be expected. By suspending one of the cylinders so that it could move freely it was demonstrated that when the vortex systems are as shown in Fig. 6 the obstacles are in equilibrium, approaching if separated, and receding from one another after being put close. The forces due to the vortex systems round obstacles placed in vibrating air which washes over them are, then, clearly sufficient to produce ridges.

If cork dust is used, fine intermediate ridges tend to form between the main ridges, and these ridges consist of the finer particles present. They are clearly due to such particles being driven by the vortex motion to a position between the two systems. If particles of uniform size, actually small wax spheres, are used, no intermediate ridges are formed.

If the vibration is very vigorous, particles are robbed from the extremities of the central ridges, and carried along from ridge to ridge until finally a very small ridge is formed near the node, which moves in slightly and collapses. Ultimately all the ridges are cleared away in this manner, and carried to a position near the node, where they build up the walls, to either side of a node, shown in Fig. 8, Plate III, forming an eye. This behaviour can easily be explained in terms of the fact of observation that, at lower intensities, the general circulation of Figs. 4 and 5 is very sluggish, and unable to overcome the effects of

the vortex system formed round an obstacle, while at higher intensities the vigour of the circulation gains on that of the vortex systems. Without going into details it may be said that when the vibration is strong the circulation, along the walls from antinode to node, carries the particles until they reach a position near the node where the intensity is just insufficient to cause vortex motion, and so to maintain a ridge; in other words, to the position where the one side of the eye is formed. This was confirmed in detail by subsidiary experiment.

In the course of the experiments a new phenomenon was observed. At the antinode a sharp disk of dust is formed, less than a millimetre thick, which is shown obliquely in Fig. 10, Plate III, and as seen by an observer looking normally to the axis of the tube in Fig. 9, Plate II. The mechanism of formation of this disk is curious. When the vibration is first started a series of deep ridges, formed by the same mechanism as those at the bottom of the tube, appears at the top of the tube, near the antinode, but ultimately they all move in to form a single antinodal disk, the downward action of gravity, which stabilises those at the bottom, leading to the disappearance of all ridges at the top but the central one. With finer particles sharper disks than that shown in Fig. 9 can be formed. These antinodal disks are very valuable for measuring sound velocity. Many precautions are required, but with care great uniformity can be obtained. Mr. D. H. Smith is working with me on this point, and, before the latest improvements, we had obtained 331·34, 331·28, 331·64, 331·52, 331·48 as values of the velocity of sound in dry air, corrected to 0° C. Even greater consistency is now being obtained. The method is, of course, available for any gas. Fig. 11 shows a series of antinodal disks in a tube, the driving diaphragm being on the left, and the closed end of the tube out of the picture on the right.

The mechanism by which dust figures are formed in Kundt's tube appears, then, to be tolerably clear, and the study of it has led to a method for measuring the velocity of sound in gases more accurate than that hitherto available. The third problem to which attention has been recently devoted in my laboratory is that of the sensitive flame, on which Mr. G. B. Brown has been working, and has recently published a series of results. The final problem of the exact method in which the sound vibrations lead to instability of the burning column of gas has not yet been solved, but a great advance has been made towards an answer.

The first point was to see if the flame is sensitive to all frequencies within a certain range, or only to particular frequencies. In order to avoid some of the complications attach-

ing to a hot stream of gas, that is, to a long flame, the main experiments were carried out with a sensitive stream of air, rendered visible by an admixture of cigarette smoke. The valve technique allows a steady note of any frequency to be produced. Mr. Brown has found that such a stream is sensitive to certain frequencies only, the main frequencies lying in the neighbourhood of higher harmonics of one fundamental frequency, although it is not at present clear if any particular significance can be attached to this relation. They are the same for different jets and a stream of one gas, but the critical frequencies for unlit gas are higher than those for air, and those for lit gas higher still.

Another very important point which Mr. Brown has established is that the statement made in the textbooks, to the effect that the instability produced by a sound is essentially the same as that produced by an increase of pressure which leads to flaring, is wrong. Increase of gas pressure leads to a confused turbulence, but stroboscopic observation reveals the fact that a pure note leads to a flickering of the stream, with alternate disengagement of a vortex first to one side and then to the other, forming a double system something like what is known as a Karman vortex street, but with the two sides of the " street " diverging so as to form a V instead of being parallel. The general behaviour is reminiscent of what takes place in edge tones, to which the mechanism of the sensitive flame would appear to be closely related.

This account is necessarily very condensed, and many questions, neglected here, which will no doubt suggest themselves to readers, are handled in the original papers. It is hoped that it may serve to suggest that there is still room for research in many old problems which are casually assumed to be exhausted. If the story here told has a moral it is, perhaps, that the hydrodynamics of real fluids has little relation either to the conventions of the older textbooks or to the theoretical results obtained with the perfect fluids so dear to the applied mathematician. The hydrodynamics of vortex motion still offer a field for experiment, in which the beauty of the phenomena offers a rare reward.

CHRISTOPHER COLUMBUS AND THE DISCOVERY OF MAGNETIC VARIATION

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Introduction

There are two problems in connection with the early history of magnetism which have long aroused a considerable amount of interest and speculation: the first, When and how did the mariners' compass first come into use in western Europe? the second, When and by whom was it first observed that the magnetic needle does not point to the geographical pole, but is deflected either to the east or west? Closely connected with this second question is that of the discovery that the variation (or, as it is now called, the declination) is itself not uniform, but varies with locality, and is also subject to a slow change with time.

Though we are not here concerned with the introduction of the mariners' compass into Europe, yet it may be said that this took place some time before the close of the twelfth century: a pivoted needle is mentioned as one of the essentials of a well-equipped ship by Alexander Neckham in his *De nominibus utensilium*, and is also referred to in his *De naturis rerum* in a manner which leaves no doubt that its use was well known at this time (*c.* 1190).[1] This reference is almost certainly the earliest which has so far come to light, but even if the allusion to the compass in the satirical poem, " La Bible," by Barbarossa's minstrel, Guyot de Provins, is but little later, Neckham's is of special interest: to us, because he was an Englishman; and generally, because it occurs in a serious, one might almost say " scientific," work.[2] As to the manner in which the West first became

[1] Alexander Neckham was born at St. Albans in 1157. The *De naturis rerum* cannot be dated with certainty, but it is quoted at length in a Chronicle (formerly ascribed to John of Brompton) which closes with the accession of King John in 1199.

[2] The *De naturis rerum* is also interesting, in that Neckham attempts (lib. II, cap. 98, " De vi attractiva ") to account for the attraction of the magnet for iron, as well as for that of amber for chaff, on the theory of " similarity and dissimilarity," which is again met with in the sixteenth century (*e.g.* in Fracastoro's *De Sympathia et Antipathia rerum*, 1546).

acquainted with the use of the mariners' compass, it is an attractive theory, and one with much to be said in its favour, that in this, too, the West profited by the closer contact with the East brought about through the Crusades.

1. Columbus and the Discovery of Variation

The discovery that the compass needle does not point to the geographical pole is now almost universally credited to Christopher Columbus: few accounts, however brief, of the famous voyage of 1492 fail to make some mention of the consternation caused among the crews by the peculiar behaviour of the magnetic needles. And indeed, whatever light recent research has thrown on the knowledge of variation before Columbus, no *recorded observation* has yet come to light which is earlier than the entry in Columbus's Diary for Thursday, September 13, 1492:

"En este dia, al comienzo de la noche, las agujas noruesteaban, y a la mañana noruesteaban algun tanto."[1]

And again, referring to Monday, September 17:

"Tomaron los pilotos el Norte marcandolo, y hallaron que las agujas noruesteaban una gran cuarta, y temian los marineros, y estaban penados y no decian de que. Conociolo el Almirante, mando que tornasen a marcar el Norte en amaneciendo, y hallaron que estaban buenas las agujas; la causa fue que la estrella que parece hace movimiento y no las agujas."[2]

These extracts are taken from the edition of Columbus's Diary published by Navarrete in his *Coleccion de Viages* (1825)[3]: a most useful work, as it contains all the extant documents written by Columbus in connection with his voyages, each document certified to have been correctly copied from the original MSS. with, in most instances, the name of the copyist.

It is generally said that Columbus kept two diaries—a private one, and also an official one to which the pilots had access; that

[1] "This day, at nightfall, the needles deviated to the north-west, and on the morrow they deviated slightly (? about the same) in the same direction."

[2] "The pilots took an observation of the north, and found that the needles deviated a good quarter to the north-west, and the mariners were afraid, and were dismayed, and did not say why. And the admiral observed it, and bade them repeat the observation of the north at dawn, and they found that the needles were correct; the reason was that the star which they saw moved, and not the needles."

[3] Martin Fernandez de Navarrete: *Coleccion de los viages y descubrimientos que hicieron por mar los Españoles desde fines del siglo XV* (5 vols., 1825–37), vol. I, pp. 8–9.

the number of leagues covered was always made to appear less than was actually the case, so as not to alarm the crews. I cannot, however, find any record of such an official diary; perhaps the statement rests merely on the fact that Columbus nearly always adds a second, slightly smaller, estimate of the distance covered: thus, for September 13, "sailed 33 leagues west, and reckoned 3 or 4 less," and for September 17, "sailed 50 leagues west and reckoned only 47." This seems rather to point to the desire of a cautious man to avoid falling into the natural error of over-estimating the distance covered. The experienced pilots who accompanied the expedition could probably estimate the distance no less accurately than Columbus, for it must be remembered that at this time the method of estimating the speed of the ship by the "log" had not been introduced, and that all estimates were entirely a matter of experience, depending on knowledge of wind, current, and the sailing qualities of the ship; an experienced pilot could probably arrive at a fair estimate of the ship's speed from the extent to which the sails filled.

Nor does it seem likely that such an innocent subterfuge on Columbus's part would have gone far towards allaying the fears of the crews, who, according to one early account,[1] were so incensed against him that they wished to throw him overboard, and greatly resented the action of Ferdinand and Isabella of Spain in entrusting them to the care of such a man. So sullen and rebellious did the captains and crews prove, with their repeated cry of "turn back to Spain," that it must indeed have seemed to Columbus that Nature herself was taking sides against him when the behaviour of the needles so added to his difficulties. Surely he would gladly have foregone any additional honour that might come to him as a result of this other, scientific, discovery.

Yet, just as the new world which he discovered is named after another, so, by some strange chance, the name of Columbus is scarcely ever mentioned in connection with the discovery of magnetic variation in works produced before the beginning of the nineteenth century. I have, in fact, met only one in which the discovery is ascribed to Columbus[2]; in every other case it is some other name which is mentioned, most frequently that of Sebastian Cabot. This is difficult to account for, in view of the fact that almost from the time of Columbus there has been a steadily growing body of purely Columban literature, made up of the various editions and translations of Columbus's diaries

[1] Gonzalo Fernandez de Oviedo y Valdés: *La Historia general de las Indias* (1535), book II, chap. 5.

[2] V. A. Formaleoni: *Saggio sulla nautica antica de' Veneziani* (Venice, 1783).

and letters, and of the accounts left by others who had first-hand knowledge of the voyages. These works range in date from 1535 to 1930, and it is safe to say that few, if any, of them omit to refer to the behaviour of the magnetic needles. I cannot say with certainty when Columbus's diaries were first published; but the text by Bartolomè de las Casas,[1] who accompanied Columbus in 1493 on his second voyage, and who afterwards became known as the "Apostle of the Indians," dates from about the middle of the sixteenth century. The earliest published reference to Columbus's observation of the variation that I have come across is to be found in a history of the Indies by the Spanish historian Oviedo,[2] published in 1535. Book II, chap. 5, of this work describes the voyage of 1492, and mentions the erratic behaviour of the needles which so alarmed the mariners shortly after the fleet left the Canary Islands. The passage in question is involved, and might very well be construed without any reference to "needles" at all, since Oviedo here uses the word "aguajes," which might be taken either for "agujas" (needles) or for "aguages" (currents), the latter certainly fitting the context the better; but chap. 11, in which the subject of the variation is discussed, opens with a statement to the effect that "it has already been mentioned in chap. 5 that the needles (agujas) proved unreliable," and there is no other passage in the whole of chap. 5 to which this statement could refer. An Italian version of Oviedo's *Historia* is included in Ramusio's *Voyages*,[3] but here "aguajes" is rendered "correnti" (currents), while a French version [4] published in 1555 renders it "agitations des eaues," so that in neither of these works is there any mention of the needles in connection with Columbus. This omission, and the discussion on variation in chap. 11 of the *Historia*, are doubtless what led Fournier [5] to ascribe the discovery of variation to Oviedo himself, as it may reasonably be assumed that he used the French version. This,

[1] Bartolomè de las Casas: *Diario del Almirante D. Christobel Colòn* (Santiago, 1864).

[2] Gonzalo Fernandez de Oviedo y Valdès: *La Historia general de las Indias* (1535).

An English version was published in 1555 in a work entitled, *The Decades of the newe worlde or weste India, contaynyng the navigations and conquestes of the Spanyardes. Wrytten in the Latine tounge by Peter Martyr of Angleria and translated into Englysshe by Richard Eden.* This, however, seems to be based more on an earlier work by Oviedo, the *Summario de la natural hystoria de las Indias* (1526), and contains no reference to the magnetic needles.

[3] Giovanni Battista Ramusio: *Navigationi et Viaggi* (Venice, 1556), vol. III, fol. 81.

[4] J. Poleur: *L'Histoire naturelle et généralle des Indes. Traduicte de Castillan en François* (Paris, 1555).

[5] Georges Fournier: *Hydrographie, contenant La Théorie et la Pratique de Toutes les Parties de la Navigation* (Paris, 1643), book XI, p. 541.

then, is the probable source of the statement, frequently met with, that Oviedo discovered variation. Usually one finds the name of Sebastian Cabot coupled with that of Oviedo. As far as I have been able to discover, all claims made on behalf of Cabot rest ultimately on nothing more substantial than a statement, made by Livio Sanuto in his *Geografia*,[1] to the effect that he, Sanuto, had it from a friend of his, Guido Gianneti da Fano, a man worthy of the highest esteem by reason of his learning, that the Venetian, Sebastian Cabot, had discovered this great secret on his voyage to the Indies. And again, Fontenelle tells us[2] that:

> " Le premier qui l'ait publiée (*i.e.* la déclinaison) a été Caboto, Navigateur Vénitien, en 1549. Mais M. Delisle a un Manuscrit d'un Pilote Dieppois nommé Crignon, qui est un Ouvrage dedié à l'Amiral Chabot en 1534, et où il est fait mention de la déclinaison de l'Aiman."

And on the strength of this the unknown Crignon is hailed as the discoverer of variation. It does indeed seem remarkable that these few comparatively obscure passages, quoted and requoted, should have so successfully excluded Christopher Columbus from any credit in connection with the discovery of magnetic variation for the space of more than 300 years.

2. Genoese and Flemish Compasses

Valuable as are the diaries in establishing beyond all question the fact that Columbus did observe and record the variation of the compass in 1492, yet for our present purpose even more valuable is the account left by his son Fernando. The original Spanish text of this " Life of his Father " is apparently no longer extant, but it was fortunately translated into Italian by Alfonso de Ulloa in 1571,[3] to be later retranslated into Spanish by Gonzalez de Barcia in 1748.[4] Ulloa's Italian version was

[1] M. Livio Sanuto: *Geografia distinta in XII libri, ne quali, oltra l'esplicatione di molti luoghi di Tolomeo, e della Bussola, e dell' Aguglia* (Venice, 1588), fol. 2.

[2] *Histoire de l'Académie Royale des Sciences* (1712), p. 18.

[3] *Historie del S. D. Fernando Colombo, nell quali s'ha particolare, e vera relatione della vita e de' fatti dell' Ammiraglio D. Christoforo Colombo, suo padre; nuovamente di lingua Spagnuola tradotte nell' Italiana dal S. Alfonso Ulloa* (Venice, 1571).

[4] Gonzalez de Barcia: " La Historia del Almirante Don Christoval Colon, que compuso en Castellano Don Fernando Colon, su hijo, y traduxo en Toscano Alfonso de Ulloa, vuelta a traducir en Castellano, por no parecer el original " (*Historiadores Primitivos de las Indias Occidentales*, vol. I, Madrid, 1748).

translated into English by Churchill in 1732.[1] It is interesting to see that a new Italian edition was published as recently as 1930. Now the passages in Fernando's account, which refer to the behaviour of the needles, mention several points of considerable interest which are not given in the diaries themselves. Thus, for September 13 and 17, 1492:

"On the 13th of September, he found that at night fall, the needle vary'd half a point towards the N.E., and at break of day, half a point more, by which he understood that the needle did not point at the north star, but at some other fix'd and visible point. This variation no man had observ'd before, and therefore he had occasion to be surpriz'd at it, but he was more amaz'd the 3rd day after, when he was almost 100 leagues further; for at night the needles vary'd about a point to the north east, and in the morning they pointed upon the star."

Churchill's Translation.[2]

(Ulloa's text of 1571 requires "invisible" in place of "visible" and "north-west" for "north-east.")

We have here a definite statement that the variation altered with the position of the ship, and that a point was reached where it was nil; and also a reasonable explanation of the phenomenon is put forward.

The most significant passage, however, is to be found in the account of the return voyage on the completion of Columbus's second visit to the Indies. As this passage is of considerable importance, I shall give Ulloa's Italian version as well as the translation by Churchill. The extract, which refers to May 20, 1496, when Columbus was in the neighbourhood of the Azores, runs:

"Questa matina le aguglie Fiaminghe noruestavano, come sogliono, una quarta; e le Genovesi, che solevano conformarsi con quelle, non noruestavano se non poco: e per l'avenire hanno a noruestare andando il Leste, che e segno, che ci ritroviano cento leghe, o alquanto piu all' Occidente delle isole de gli Astori: percioche, quando furono appunto cento, allhora era in mare poca herba di ramuscelli sparsi e le aguglie Fiaminghe noruestavano una quarta, e le Genovesi percotevano la Tramontana; e, quando saremo piu al Leste nordeste, faranno alcuna cosa. Il che si verifico subito la Domenica sequente a' XXII di Maggio. Del quale indicio, e dalla certezza del suo punto

[1] A. & J. Churchill: "The Life of Christopher Columbus, written by his son D. Ferdinand Columbus" (Churchill's *Collection of Voyages*, vol. II (1732)).
[2] *Ibid.*, chap. 18, p. 524.

conobbe allhora, che si ritrovano cento leghe lontano dalle isole de gli Astori. Di che egli si maraviglia, et attribuisce la cagione alla differenza della Calamita, con che si temperano le aguglie; percioche fino a quella linea tutte noruestano una quarta; e quivi le une perseverano, e le altre, che sono le Genovesi, percuotono giustamente la stella."[1]

Churchill's translation is as follows:

"This morning the Dutch compasses vary'd as they used to do, a point; and those of Genoa, that used to agree with them, vary'd but a very little, but afterwards sailing east vary more, which is a sign we are a 100 leagues, or somewhat more, west of the Azores; for when we were just 100, there were but a few scatter'd weeds in the sea; and the Dutch needles vary'd a point, those of Genoa cutting the north point; and when we are somewhat farther E.N.E. they will alter again; which was verified on Sunday following being the 22nd day of May; by which and the exactness of his account, he found he was 100 leagues from the islands Azores, which he was somewhat surpriz'd at, and assigned this difference to the several sorts of load-stones the needles are made by; for till they come to that longitude they all vary'd a point, and there some held it; and those of Genoa exactly cut the north star."[2]

That there was by now no little curiosity as to what the needles were going to do is seen from the following passage, which refers to 1498, shortly after Columbus set out on his third voyage:

"He also says, that this same night, being Thursday the 16th of August, the compasses which till now had not vary'd, did at this time, at least a point and a half, and some of them two points, wherein there could be no mistake, because several persons had always watched to observe it."[3]

(In both of these passages Churchill translates "noruestear" by "to vary," instead of the more exact "to vary to the north-west.")

The point of greatest interest in the first of these two passages is the reference to two distinct types of compass, the Genoese and the Flemish, the essential difference between them being that the Flemish compasses pointed one quarter (= one point = $11\frac{1}{4}°$) west of north (*i.e.* N. by W.) when the Genoese pointed to the north.

It is perhaps advisable at this stage to draw attention to the

[1] Ulloa: *Historie del S. D. F. Colombo*, chap. 64, ff. 148–9.
[2] Churchill: *Collection of Voyages*, vol. II, chap. 64, p. 580.
[3] *Ibid.*, chap. 73, p. 587.

essential difference which existed then, as now, between a mariners' compass and one intended for use on land; and to indicate the manner in which either of these could be made to allow for a fixed magnetic variation. In the ordinary land compass the needle swings freely on a pivot in the centre of a circular compass card which is fixed to the base of the instrument: to allow for an easterly variation of 11¼°, it is only necessary to draw a line through the centre of the card at an angle of 11¼° to the east of north of the north-south line marked on the card. When the needle is directly over this auxiliary line, the compass is correctly oriented with the north-south line pointing to the geographical pole. In the mariners' compass, on the other hand, the compass card is attached to the magnetised needle, and swings with it, the needle being hidden by the card; the direction in which the ship is sailing is shown by the point of the compass card which comes beneath a fixed mark on the compass box, in line with the bows of the ship. With such a compass, allowance could be made for an easterly variation of 11¼° by fixing the compass card on to the needle in such a way that the points N. by E. and S. by W. are directly over the two ends of the needle. Then when the needle points to the magnetic pole, the fleur-de-lis marking the north will point to the geographical pole. If the ship is sailing true west, the needle and fleur-de-lis still point to the magnetic and geographical poles respectively, but the point marked "west" on the compass card is in line with the bows of the ship. Such a compass will give true directions, provided only that the variation does not alter.

Now there is convincing proof that mariners' compasses which allowed for variation in this way were in wide use at the end of the sixteenth century; and were, in fact, known as Flemish (or Dutch) compasses, the others being known as Italian compasses. In 1595 the Dutchman, Willem Barentsz, published a nautical chart of the Mediterranean Sea.[1] The maps, like those in all nautical charts of this period, are crossed by a number of lines called "loxodromes" (or rhumbs), the charts themselves being called "loxodromic charts."[2] These lines radiate from regularly spaced points, and were used for determining directions. In Barentsz's maps, when the area represented is small, such as the part of the Mediterranean between the south coast of Spain and the coast of Africa, the full complement of lines is not given, the water region being crossed by a

[1] Willem Barentsz: *Description de la Mer Méditerranée* (1599). (Dutch edition: *Caertboek vande Mittlandtsche Zee*, 1595).

[2] G. R. Putnam: *Nautical Charts* (1908), p. 7. The method of using these lines for navigation seems quite unknown. Peschel gives an account in his *Der Atlas des Andrea Bianco*, but it is entirely wrong. The lines will be dealt with in a subsequent paper.

single set of lines radiating from a conveniently placed point. Such a set consists of 32 lines, corresponding to the 32 points of the compass. Now the interesting point about Barentsz's chart for us is that some of these small-area maps show a second set of 32 lines radiating from another point some distance from the first, this second set being turned bodily through half a point (= 6°) through north to west (Fig. 1). The second set is

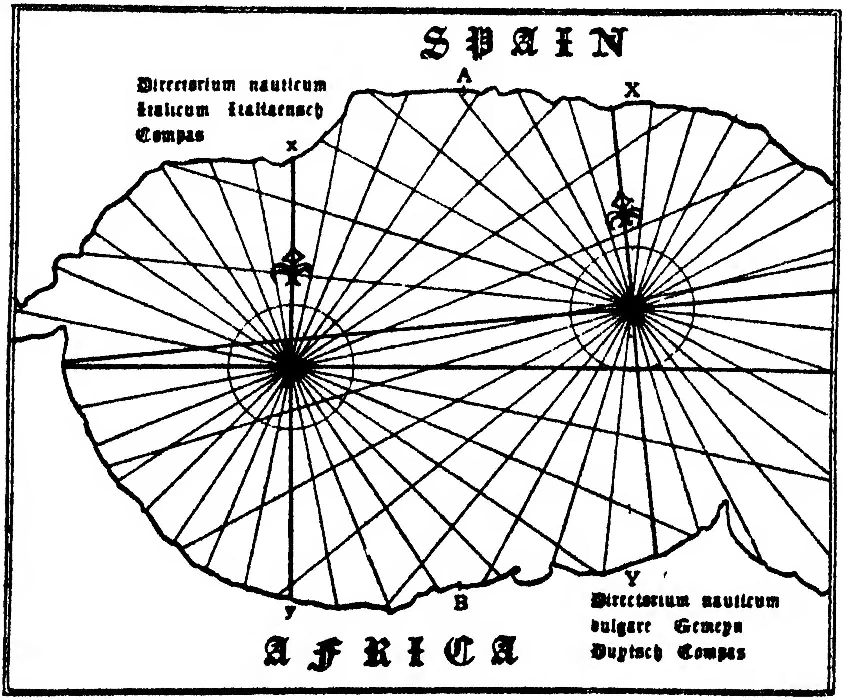


FIG. 1.—Arrangement of Italian and Dutch Compasses shown in Barentsz's Chart of 1599. The Dutch compass is turned 6° through north to west, corresponding to a magnetic variation of 6° E. XY—position of the needle in the Dutch Compass. xy—position of the needle in the Italian compass. The port *A* is shown to be due (magnetic) north of *B* by the Italian compass, but 6° east of (true) north by the Dutch compass.

labelled "Directorium nauticum vulgare. Gemeyn Duytsch Compas" (ordinary Dutch compass), while the first set is labelled "Directorium nauticum Italicum. Italiaensch Compas." In the introductory matter at the beginning of the chart there is a "warning to the reader," which is so interesting that I propose to give it in full, especially as I have seen no reference to it in other articles on the Genoese and Flemish compasses. It runs:

"Lecteur ami, vous debuez scavoir, que nous avons mis en aucunes des Cartes, comprinces en nostre livre, deux sortes de

Compas marins : nommement le Compas Flameng, et le Compas Italien, et ce pour la raison que ie vous vay dire. Tout Pilote, ou Navigant ayant la connoissance des Cartes marins, peult facilement veoir et entendre, qu'en les cartes marins, faictes en Italie, les terres et païs ne sont pas mises soubz leur vraye et deue haulteur, ou elevation de Pole, lesquelles par tout sont mises aucunefois deux, aucunefois trois degrez plus Septentrionales, quelles sont. Ce qui se voit en aucunes de leur cartes, ou la Ville de Venise se trouve mise soubz la haulteur de 48 degrez, ou 48 degrez 30 minut. Laquelle a la verité n'est que 45 degrez 15 minut, ou au plus 45 degrez et demy : tellement que la faulte est d'environ trois degrez : ce qu'a esté par les Pilotes et Navieurs Hollandois diligemment observé. Semblablement Genua s'y trouve mise soubz la haulteur de 46 degrez et demi, ou la vraye haulteur n'est que 44 degrez et demi, de sorte que la faulte est de deux degrez, et ainsi de tous autres costes et Capes ensuivantes. Ce qui advient par leur Compas de mer. Car en Italie l'aiguille ou acier du Compas se met droictement soubz la fleur de Lys, comme mesmes en Italie iay experimenté : et nous aultres mettons l'aiguille ou acier une demy ligne ou plus vers l'Est, comme a tous est notoire. Ores a cause que les Italiens ordonnent, comme dict est, leur aiguille du Compas, aussi ont ils es [? en] Cartes Marines, mis les terres et costes selon leur Compas, sans prendre consideration aucune de la haulteur Polaire : ce qui est cause que les terres et places se monstrent trop Septentrionales, et de plus grande elevation, que le vraye requiert. Ce qui est a sesmerveiller, et facilement se peult corriger : par ce que le temps y est ordinairement serein, et que les costes de la mer Mediterrane, et de Levant, si voient clairement, de maniere qu'on y peult facilement mesurer la haulteur Polaire, et ainsi corriger leur Cartes marines. Neantmoins a cause que sur la mer Mediterrane l'air est tousiours serein, et que les terres sont de haulte assiete et situation, l'Italien faict peu de compte de la haulteur du Pole. Car quant l'une terre se perd de veue, incontinent l'autre se decouvre et manifeste, tellement qu'il neglige de mesurer la haulteur du Pole, mais institue tousiours la navigation par les courses. Parquoy iay bien voulu advertir ceulx qui desirent hanter et naviguer la mer de Levant, d'en prendre bonne garde, veu qu'on ne scauroit iustement naviger la mer Mediterrane : sur la Carte Marine faicte en Italie, avec le Compas Hollandois, pour parvenir a la terre vers laquelle on cuideroit prendre son cours, a cause que la difference seroit bien d'une demy ligne, ou plus. Car prenes le cas que vous vouldries prendre vostre cours iustement a l'est, alors navigant par le mesme cours 40 lieues a l'est, vous declinerés bien six lieues au sud, que ne cuiderés, pour la raison susditte. Plusieurs aultres raisons se pourroient

deduire sur cette chose, lesquelles mettrons en oubly, par ce que nostre intention est de n'en parler plus amplement."[1]

We have here a clear statement that in the Italian compasses the needle was placed directly underneath the fleur-de-lis marking the north, whereas in the Dutch compasses it was set half a point, or about 6°, to the east of north (the word "ligne" used in the text is equivalent to the "point" of English writers, or the "cuarta" of the Spanish; some modern German writers use the word "Strich" in the same way).

The Dutch compasses, then, were at this time constructed so as to allow for a variation of 6° E. Fig. 1 may at first glance

[1] *Translation.*—"Friend Reader, you must know that, on some of the maps included in our book, we have put two kinds of mariners' compass: namely, the Flemish compass and the Italian compass, and this for the reason that I am going to tell you. Every Pilot or Navigator who knows about mariners' charts will readily see and understand that in the mariners' charts made in Italy, the lands and countries are not put down under their true and proper latitude or Polar Elevation, but are everywhere set sometimes two, sometimes three degrees farther north than they are. This is seen in some of their charts, where the City of Venice is shown in latitude 48 degrees, or 48 degrees 30 minutes. Whereas in reality it is not more than 45 degrees 15 minutes, or at most 45 degrees and a half, so that the error is about three degrees, which has been carefully noticed by the Dutch Pilots and Navigators. Similarly, Genoa is there set down under latitude 46 degrees and a half, whereas the true latitude is only 44 degrees and a half, so that the error is about two degrees, and so for all other shores and headlands following. [*Note.*—In the list of courses from one Mediterranean port to another which is included in the chart.] This comes about through their mariners' compass. For in Italy the needle or steel of the compass is set directly beneath the fleur-de-lis, as, in Italy, I have made trial [*Note.*—By removing the compass card and attached needle from the compass box]. and we others set the needle or steel a half-point or more towards the East, as is well-known to all. Now, because the Italians arrange their compass needle as stated, they have also, in their mariners' charts, set down the lands and shores according to their compass, without taking the Polar Elevation into any account: this is why the lands and places are shown too far north and of higher latitude than is really the case. This is to be wondered at, and could easily be rectified, since the weather there is usually calm, and the shores of the Mediterranean and of the Levant are clearly visible, so that the Polar Elevation could easily be measured, and thus their nautical charts corrected. Nevertheless, because in the Mediterranean the air is always calm and the lands are high, the Italian pays little attention to Polar Elevation. For when the one land is lost to view, immediately the other comes into view, so that he gives no thought to the Polar Elevation, but always navigates by the rhumb lines. Wherefore I want to warn those who wish to frequent and navigate the Levant, to give heed to this, since one would not be able to navigate the Mediterranean correctly with a mariners' chart made in Italy, and a Dutch compass, so as to arrive at the land towards which one wished to set one's course, because the difference would be quite half a point or more. For suppose you wished to set your course due East, then in sailing 40 leagues to the east on the same course, you would deviate quite six leagues farther south than you wish, for the reason given. Several other reasons could be given on this matter, but we will leave them, for it is not our intention to speak of it more fully."

appear to contradict this, since the fleur-de-lis in the Dutch compass is deflected to the *west*; this, of course, is as it should be: in the Dutch compasses the needle is to the east of north (indicated by the fleur-de-lis), so that the fleur-de-lis is always to the west of the position taken up by the needle, that is, a direction indicated by a Dutch compass would always appear to be half a point west through north of the same direction as indicated by an Italian compass, in which needle and fleur-de-lis coincide, since the needles are pointing in the same direction in each case. Thus, in Fig. 1, the port A is magnetic north of the port B, since AB is parallel to xy, the position of the north-south line, and also of the needle, in the Italian compass; the corresponding line in the Dutch compass is XY, which therefore marks the position of the needle, and also shows that the true bearing of A relative to B is half a point east of north.

It has often been said [1] that the variation of the compass had not been observed by the Mediterranean navigators of Columbus's time because the value in the Mediterranean was then very small. I do not know on what grounds the statement as to the value in the Mediterranean is based, but Georg Hartmann says [2] that he measured the variation at Rome early in the sixteenth century, and found it to be 6° E., not such a very small value. It seems to me that we have a more likely explanation in the statement by Barentsz, that the excellent visibility in the Mediterranean led the navigators to rely more on the compass and sight than on astronomical methods, so that the discrepancy between true directions and compass directions was not detected. That the Italians did not naturally turn to their astronomical instruments is borne out by the error of 2° or 3° in the latitudes of such places as Venice and Genoa, an error which, as Barentsz remarks, could so easily have been rectified (his own values for the latitudes of these two places are practically correct). On the other hand, the Flemish navigators, sailing in less kindly waters, may well have been compelled to rely more on their compasses and astronomical observations, and so detected the difference between true and magnetic bearings. It would seem reasonable, then, to look to the Flemings for the real discoverers of magnetic variation.

Barentsz's remarks also throw light on another matter which has proved rather puzzling. A careful comparison which I have made between an early fifteenth-century chart by Andrea Bianco and a modern atlas shows a consistent error of 5° to 6° West over the whole Mediterranean area: thus, on this chart,

[1] By G. R. Putnam, *Nautical Charts* (1908), p. 7, and others.

[2] Georg Hartmann: *Neigung der Magnetnadel* (1544), reprinted in Hellmann's *Neudrucke*, No. 10 (1898).

the most westerly point of Cyprus is due north of the mid-point of the Nile Delta, whereas the correct bearing is 6° E. of N.; and Arles, near Marseilles, is due north of the centre of Minorca, whereas it should be 5° E. of N.[1] This means that the chart is based on compass bearings made at a time when the variation was about 5° E., or perhaps based on an earlier chart made at such a time. In either case it was difficult to see how the use of such a chart in conjunction with true (astronomical) bearings could have failed to lead to the discovery of variation by this date (1436). For, as Barentsz says, the error, even in a short voyage, would be considerable. If, however, the Mediterranean mariners were in the habit of sailing entirely by compass until they came in sight of known landmarks, taking their bearings from the (magnetic) loxodromes (" navigation par les courses "), the difficulty disappears. It says much for the position held by the compass in the minds of these mariners that Columbus chose to weaken their faith in the stars rather than that they should lose their faith in the magnetic needles.[2]

Returning now to the account by Fernando Columbus, it is hardly possible to doubt that the Flemish and Genoese compasses to which he refers were essentially the same as the Dutch and Italian compasses described by Barentsz; that even at the time of Columbus the Flemings were using compasses which made due allowance for magnetic variation, a phenomenon which they must in that case already have known of for some considerable time. The very accounts of Columbus's voyages seem therefore to contain strong evidence in favour of a Pre-Columban knowledge of variation.

There are, it will be noticed, several inconsistencies in Fernando's account. For instance, how could it be that the Genoese and Flemish compasses had agreed up to a certain time and only then began to disagree? Surely, with the cards fixed differently to the needles, they must always have indicated different directions. And how was it that the disagreement was not noticed on the outgoing voyage of 1493? Or, for that matter, even before the time of Columbus? On this last point,

[1] Since making this comparison, I notice that Bertelli also draws attention to this 5° error. (Timoteo Bertelli: *Declinazione magnetica e la sua variazione nello spazio scoperte da Cristoforo Colombo.* Raccolta di documenti, part 4, vol. II, p. 49 (1892).

[2] I refer to the extract from the Diary for September 17, given above. The explanation offered here, namely, that the needles still pointed north, but the north star had moved, was probably given to restore the faith of the mariners in the needles. Columbus himself seems to have believed that the needles did not point to the Pole star at all, but to " some other fixed and invisible point." The reference in Fernando's account to the mode of preparation with different kinds of lodestone applies, of course, to the difference in behaviour of the Flemish and Genoese compasses.

probably Wolkenhauer's suggestion [1] is as good as any that can be offered: that this was the first occasion on which the two kinds were used side by side, and so comparison invited. These difficulties led Bertelli [2] to discredit the value of the account altogether as evidence of a pre-Columban knowledge of variation. He suggests that the Flemish compasses were badly made, and did erratic things which defy explanation. This idea hardly seems tenable, especially in the light of Barentsz's chart, of which Bertelli may not have known. And surely it says much for the reputation enjoyed by the Flemish instruments that Columbus should have provided himself with some for the second voyage, for one can readily believe that in the interval between the two voyages he took care to secure the best instruments available, especially after his first experience (there is no mention of the Flemish compasses in the account of the first voyage). It must be remembered that Bertelli, writing for the fourth centenary of the discovery of America, is rather inclined to cast doubt on anything which points to a knowledge of variation before Columbus, to whom he would give the full credit for its discovery. Nothing, however, is to be gained here by entering into a discussion of the suggestions which have been made in the attempt to reconcile the conflicting statements in this account; for us the central fact remains: the Flemings were, at the end of the fifteenth century as at the end of the sixteenth, constructing mariners' compasses in which the fleur-de-lis indicated a direction west by a definite amount of the direction indicated by the Mediterranean compasses. The only reasonable supposition is that this was a deliberate attempt to correct for an easterly variation of an equal amount, 1 point or $11\frac{1}{4}°$.

One other point remains to be mentioned before leaving the subject of the Flemish compasses. It is accepted as one of the landmarks in the history of magnetic variation that Gellibrand discovered, in the year 1635, that the variation changes with time. To quote his own words:

"Thus hitherto (according to the Tenents of all our Magneticall Philosophers) we have supposed the variations of all particular places to continue one and the same: So that when a Seaman shall happly returne to a place where formerly he found the same variation, he may hence conclude, he is in the same former Longitude. For it is the Assertion of Mr. Dr.

[1] August Wolkenhauer: "Beiträge zur Geschichte der Kartographie und Nautik des 15 bis 17 Jahr," published in *Mitteilungen der Geographische Gesellschaft in München*, vol. I, heft 2 (1905), p. 161.

[2] Timoteo Bertelli: *Declinazione magnetica e la sua variazione nello spazio scoperte da Cristoforo Colombo*. Raccolta di documenti, part 4, vol. II (1892), pp. 16, 33.

Gilberts. Variatio unicuiusq; Loci constans est, that is to say, the same place doth alwayes retaine the same variation. Neither hath this Assertion (for ought I ever heard) been questioned by any man." [1]

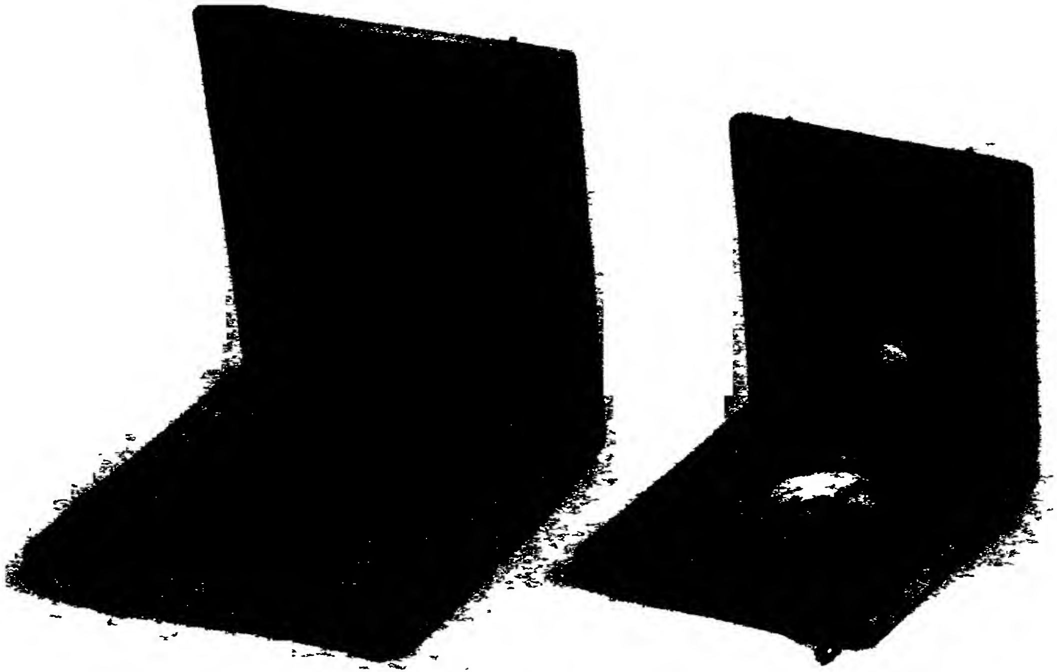
Now if, at the close of the fifteenth century, the Flemings were making mariners' compasses which allowed for a variation of 11½° E., and at the close of the sixteenth century were so making them as to allow for a variation of 6° E., can we escape the conclusion that at some time during the course of the sixteenth century the Flemings found that the variation had changed, and altered their compasses accordingly?

3. German Pocket Sundials

That the adjustment of the Flemish compasses corresponded to a variation of 11½° E. is in itself significant, for this is the value which we should expect to find on the strength of the evidence which we have now to consider. This time we shall be concerned, not with the mariners' compass, but with the ordinary land compass, which, as already pointed out, could be quite easily corrected for a fixed variation by marking another line through the centre at an angle with the true north-south line, to indicate the magnetic north. Now the simple land compass is essentially an instrument for orienting stationary objects: it would soon prove impracticable for guiding a moving object on a course other than due north or south; the modern service compass has to have a special arrangement so that it can be used for marching on a compass bearing. One is at first inclined to wonder what object in use by the landsman at this time could have required such careful orienting that allowance should be made for the variation of the needle. There is, however, one object which was in wide and everyday use at this time—the sundial. A large stationary sundial would, of course, probably be correctly oriented by reference to the position of the shadow at midday; but at some time towards the middle of the fifteenth century there came into use in Germany a type of small portable sundial, which, owing to its convenient size, may be termed a "pocket" sundial.

Now the construction of a portable sundial presents several difficulties: the whole instrument must be compact; the gnomon for casting the shadow must be collapsible, so that it does not get damaged; it must be possible to orient the dial readily and accurately; and, if it is intended for use in different

[1] Henry Gellibrand: *A Discourse Mathematical on the Variation of the Magneticall Needle* (1635), pp. 6, 7.



TWO IVORY POCKET SUNDIALS BY HANS TROSCHEL OF NURNBERG (About $\frac{2}{3}$ actual size)

Dated (left) 1623; (right) 1607 In each case the arrow just beneath the compass needle shows an easterly variation of half a point (i.e. 6°), while a second line to the left shows a large westerly variation (in the left about 2 points, in the right about 1 point) This second line is clearly a later addition Neither of the dials has a (true) north-south line, but each has a (true) east west line Holes in the upper half of the cover of the right-hand dial bear numbers corresponding to the latitudes of the places named in the lower half, so that the angle of the string (missing) can be adjusted for different latitudes

(Photo published by kind permission of the Trustees of the British Museum)

countries, it must be possible to alter the angle of the gnomon, for a sundial with a fixed gnomon will only give correct time in the latitude for which it is made, since the angle of the gnomon must equal the latitude of the place where the dial is set up. The way in which all these difficulties were overcome by the mediæval German craftsman is really a marvel of ingenuity; as one might expect, since for nearly 200 years the centre of the industry was at Nürnberg, that home of mediæval craftsmanship and ingenuity. (How many know, I wonder, that a Nürnberg craftsman, Hanns Ehmann, who died in 1551, constructed a combination lock which required no key, but opened for a given arrangement of numbers or letters?)

Before going on to describe these pocket sundials, I should here mention the very fine collection in the possession of the British Museum (Department of Mediæval Antiquities, Bay XIV).[1] This collection includes no fewer than 19 German dials belonging to the second half of the sixteenth century and early seventeenth century, in addition to a large number of later date (eighteenth century), as well as several French dials by Dieppe makers of rather late date (early eighteenth century), and one by a Dutchman, which bears an inscription in English, and is dated 1586. None of the German dials is of very early date, as are some in the possession of the German museums: the earliest at the British Museum is one by Georg Hartmann, and bears the date 1562. All the best-known Nürnberg and Augsburg makers are, however, represented: Hanns Troschel (father and son), Georg Hartmann, Paul Reinman, Christof Schissler, and others. The accompanying Plate shows two examples of the work of Hans Troschel, that on the left being by the son.

In size the sundials vary from 2 in. to 6 in. square; some are slightly oblong; some are round; some of more ornamental shapes. The greater number are made of ivory, though many are gilt, beautifully engraved. Some of the gilt dials are very elaborate, and are generally of later date. For our purpose the ivory dials are the more important, as they seem to be nearer in design to the very early specimens in the possession of the German museums. A typical ivory dial, such as the one shown on the left in the plate, consists of two flat pieces of ivory about ½ in. thick, hinged together at the back so as to open like a book. A piece of fine cord is attached to both base and cover midway from the sides and about half-way between the centre and front edge, of such a length that when the cover is open as far as the string permits, it is at right angles to the base. This string,

[1] I wish here to express my appreciation of the courtesy which the Department extended to me in allowing the sundials to be removed from the cases for my closer examination, and also of the care which the Photographic Department took in preparing the photos of these difficult subjects.

when extended, serves as the gnomon, the angle between it and the base being determined by the latitude for which the dial is intended. In some specimens the hours are marked on the base, in others on the cover. A circular, shallow cavity is carved out approximately in the centre of the base; in the centre of this cavity is a pivot supporting a compass needle, the floor of the cavity being engraved either with a single line marking the north, or with two lines at right angles indicating the four cardinal points: midday, midnight, sunrise, sunset. The cavity is protected by a glass cover. We thus have a compact instrument; a gnomon which is out of harm's way when the dial is not in use and one which could readily be replaced if needed; and also a means of orienting the dial correctly. One very interesting specimen (Plate, right) has two lists of place-names marked on the cover, arranged so that two places with the same latitude stand side by side, with the number representing their common latitude between them: thus "Venetig. 45. Meilant." A series of holes nearer the top of the cover is marked with the same numbers in the same order, with instructions to fix the one end of the thread in the hole bearing the number corresponding to the place where the user is at the time ("den faden sitze in das lötzle deines landes polus höhe"). In this way the angle of the gnomon can be altered so as to give correct time in any of several different latitudes.

Our interest, of course, centres on the compass. To give correct time the gnomon must be set in the true meridian, so that it is necessary that allowance be made for the variation of the compass, or a considerable error will be introduced when the dial is oriented by the needle. And the specimens in the British Museum do, almost without exception, make this allowance for variation, by marking the magnetic north instead of the true north. Most of the sixteenth-century dials indicate in this way a variation of 6° E., in agreement with the Dutch compasses of Barentsz's time. In many cases there is a second line, usually gilt, not black like the first line and other markings, corresponding to a much larger westerly variation. This second line is obviously a much later addition. Both these lines can be seen in the two dials shown in the plate.

It is not so surprising that the dials in the British Museum should make allowance for variation in this way, since all of them are of later date than the middle of the sixteenth century. But about the beginning of the present century three such pocket sundials were discovered in Germany by August Wolkenhauer, and these are of very much earlier date. The earliest of the three was discovered in the Museum Ferdinandeum at Innsbrück, and bears the date 1451. It has been described

in detail by G. Hellmann.[1] Of the other two, one is in the museum at München, and bears the date 1456; while the other is in the National Museum at Nürnberg, and, though undated, can be placed about 1470, as it is engraved with a portrait of Pope Paul II (1464–71). Both of these are described by Wolkenhauer.[2] In each of these three sundials there is a line drawn to the east of true north, just as in the British Museum specimens, but in each case the line here is one point to the east, in agreement with the Flemish compasses of Columbus's time.

4. Etzlaub's Road Map of Germany

The fact that many of the sixteenth-century sundials are marked with a second line, evidently added later to adapt the dial to an altered variation, makes one think that the lines on these very early dials may also have been added some time after they were made, perhaps during the course of the first half of the sixteenth century. In the case of the Innsbrück dial, Hellmann evidently took every care to satisfy himself that this was not the case[3]; yet even so, it would seem a difficult matter to decide with absolute certainty, after the lapse of over four centuries, that this line was indeed marked on the dial at the time it was made and not fifty or one hundred years later. That the variation indicated is one point, and not half a point, as in the middle sixteenth-century dials, shows that the line, if it is a later addition, was added at a time when the accepted variation was one point, that is, about the time of the Flemish compasses mentioned by Fernando Columbus.

Fortunately, however, there is definite evidence that these sundials were being constructed to allow for magnetic variation during the second half of the fifteenth century. Towards the end of the century road-maps of Germany, prepared by Erhard Etzlaub of Nürnberg, were being printed at Nürnberg. There are, I believe, only six of these maps extant,[4] and one of them is in the British Museum.[5] The map is undated, but the Catalogue places it about 1492, in close agreement with the dates given by Wolkenhauer for those in Germany.[6] Now at the foot of the map there are instructions for orienting it correctly, and these instructions are accompanied by a figure which is seen to

[1] Gustav Hellmann: "Über die Kenntnis der magnetischen Deklination vor Christoph Columbus," published in the *Meteorologische Zeitschrift*, band 23 (1906), heft 4, pp. 145–9. The whole article deals with this sundial.

[2] August Wolkenhauer: "Beiträge zur Geschichte der Kartographie und Nautik des 15 bis 17 Jahr," published in the *Mitteilungen der Geographische Gesellschaft in München*, vol. I, heft 2 (1905), p. 161.

[3] Hellmann: *Über die Kenntnis der magnetischen Deklination*, p. 146.

[4] Erhard Etzlaub: *Das ist der Rom Weg von meylen zu meylen mit puncten verzeychnet von eyner stat zu den andern durch deutzsche lantt* (? 1492).

[5] Wolkenhauer: *Beiträge*, p. 193.

[6] *Ibid.*

represent nothing else than the base of a pocket sundial (Fig. 2). In fact, the term "Compast," like the Latin "Compassus," seems to have been used at this time to denote a portable sundial rather than a "compass" as now understood.[1] The important thing about this figure is that, like the early sundials described by Hellmann and Wolkenhauer, it has an arrow placed one point to the east of true north.[2] That this line is not a later addition is shown by the text which accompanies the figure. On the one side we have an explanation of the use of the scale and of the different values of the mile in other countries. On the other we read:

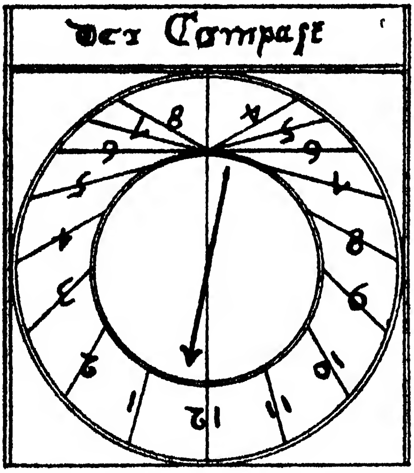


FIG. 2.—Compass shown at the Foot of Etzlaub's Road Map of Germany (? 1492). (In British Museum) The arrow is set at an angle of 11¼° to the east of the (true) north-south line The map, like most fifteenth- and sixteenth-century maps, is inverted according to our ideas, the north being at the bottom and the south at the top. Comparison with the plate will show that this figure represents nothing else but the base of a pocket sundial, in which the hinges would be at the lower edge and the string attached at the point where the lines cross at the apex of the inner circle.

"Nach dem Compast zu wandern geschigt also. Den prief legt man nyder und setzt den compast mit der seyten an eyn leysten oder gleich auf dissen Kompast und ruckt den prief pys die zungle gericht seyn so ligt der prief recht den last man ligen unverruckt und setzt dar nach den compast mit der seiten auf dye punt zweyer furgenumen Stet und merkt wye dye zung stee auf den acht teyl. Also stet sye auch wen man zwischen den selben zweyen steten wandert."[3]

[1] Hellmann: "Die Anfänge der magnetischen Beobachtungen," published in the *Zeitschrift der Gesellschaft für Erdkunde*, **32** (1897), 113.

[2] The figure, according to our ideas, is upside-down, the north being at the bottom; this is the usual arrangement in fifteenth- and sixteenth-century maps. Etzlaub's map shows Italy at the top of the map and Denmark at the bottom. I cannot recall any maps of this period which adopt our present method of putting the north at the top.

[3] "To travel by the compass one proceeds thus. The chart is laid flat, and the compass placed with its side along one edge or directly over this compass, and the chart turned till the needle (lit. 'little tongue') is in the right direction; the chart is then properly set. It is allowed to lie undisturbed, and the compass is then placed with its side on the dots marking the two chosen towns and the position of the needle noted on the dial (*i.e.* on the part marked with the hours). It occupies the same position when one travels between these two towns."

The " zungle " referred to here is, of course, the needle of the compass used to orient the map, not the arrow shown in the figure. In fact, the figure itself serves no useful purpose, and can only be intended to show the type of " compass " which Etzlaub has in mind. If the " variation line " was added later, then the original figure was without a " zungle," and so could not be called a " compast " at all. It seems then that here, at any rate, we have convincing proof that pocket sundials with the arrow set $11\frac{1}{4}°$ E. of N. were familiar objects in Germany before the time of Columbus.

5. Bianco's Nautical Chart of 1436

No discussion of Pre-Columban variation would be complete without some reference to Bianco's famous chart of 1436.[1] This chart was discovered about 1780 in the Biblioteca Publica di San Marco at Venice by V. A. Formaleoni,[2] who wrote a small book on the subject.[3] The chart quite convinced Formaleoni that the Venetians had already discovered the variation of the compass at the beginning of the fifteenth century, and had devised a method for correcting their charts accordingly. Alexander von Humboldt accepted Formaleoni's conclusion, stating in the *Kosmos* that magnetic variation is marked in Bianco's *chart.*[4] Mottelay, in a passage[5] which is almost a word for word translation of the corresponding passage in the *Kosmos,* says that " Andrea Bianco . . . published, in 1436, an atlas exhibiting *charts* of the magnetic variation." As a result it is now frequently stated that Bianco's *maps* mark variation.

As a matter of fact, Formaleoni's original statement is not based on Bianco's *maps* at all—the only markings on the maps themselves are the ordinary rhumb lines—but on a very puzzling figure given on the page of instructions at the beginning of the chart (Fig. 3) : a figure which has aroused so much interest and speculation that Bertelli is able to refer to it as " this famous figure."[6] Formaleoni takes the two points at the top of the circle to represent the geographical pole (right) and magnetic pole (left), and says that the figure is intended to correct for a variation of 18° W.—why 18° it is impossible to

[1] *Fac-simile dell' Atlante di Andrea Bianco* (published by Oscar Peschel, Venice, 1869).

[2] Giuseppe Toaldo : *Saggi di studj veneti* (Venice, 1782), Saggio 3, p. 61.

[3] Vincenzo Antonio Formaleoni : *Saggio sulla nautica antica de' Veneziani* (Venice, 1783).

[4] Alexander von Humboldt : *Kosmos* (1845–62), vol. IV, p. 53.

[5] P. F. Mottelay : *Bibliographical History of Electricity and Magnetism* (1922), p. 62.

[6] T. Bertelli : *Declinazione magnetica* (1892), p. 88.

say, unless the Venetians were also supposed to have known that there was already an error of 5° W. in Bianco's maps [1] and so corrected for a total error of 22½°. A figure such as this, however, could be taken to represent almost anything: it would be as difficult to prove that it has nothing to do with variation as to prove that it has everything to do with it. I have myself discovered that it could quite well represent a variation of 11¼° E.! The method is slightly complicated, as it makes full use of all the lines in the figure, but it does lead to the result that if you want to sail due west you must sail one point north of west by the compass! To me, the most serious objection (though no one has previously drawn attention to it) seems to be that to Bianco's ideas the figure would be *upside-down*: in his time it would have been as instinctive to put the north poles, true and magnetic, at the *bottom* of the figure, as it would be for us to put them at the top; in fact, side by side with this figure there is a compass-card, or "windrose," in which the north is shown at the bottom.

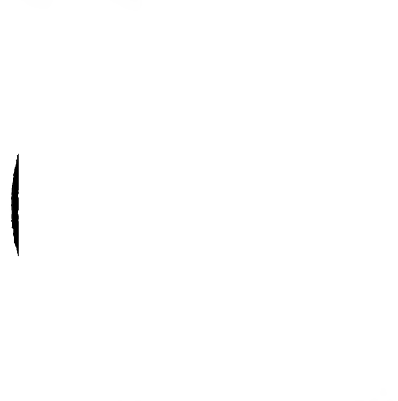


FIG. 3.—Figure shown on the page of Instructions which forms the first page of Bianco's Nautical Chart of 1436. It is on the strength of this figure *alone* that it has been asserted that Bianco's Chart marks magnetic variation.

The general conclusion at the present time is that the figure in question has nothing to do with variation, and that there is consequently nothing whatever in Bianco's chart to point to a knowledge of the phenomenon on the part of the early Venetians.

Conclusion

It appears, then, that though Christopher Columbus was the first definitely to record an observation of the variation of the compass—an observation which, in the years that followed, led to a considerable amount of interest in the subject; yet the phenomenon was already well known in northern Europe at this time, though apparently not to the Mediterranean navigators. All the evidence which we have considered—the Flemish compasses, the early German sundials, Etzlaub's map—all these taken together show that from the middle of the fifteenth century until well into the sixteenth century a varia-

[1] See above, p. 93.

tion of $11\frac{1}{4}°$ E. was accepted, and allowance made for it by the compass makers of Flanders and Germany.

Whether the real discoverer of variation will ever be known is a matter of some doubt. Did some Flemish navigator make the discovery and pass the knowledge on to the makers of the mariners' compasses, from whom it spread to the great mediæval centre of trade—Nürnberg? Or did some early German craftsman, with a bent for astronomy, find that his sundials were not true, and so hit upon the cause? It must be confessed that this latter idea makes a strong appeal, the more so as two outstanding names occur to one, as well worth bearing in mind in this connection: Purbach and his pupil Regiomontanus. Both of these were astronomers of repute. Purbach (1423–1461) left a manuscript of which the title alone is suggestive: "Compositio Compassi cum regulis ad omnia climata."[1] Nothing seems to be known of the contents of this manuscript, but in all probability it dealt with the adjustment of the sundial ("compassus") for different latitudes ("climata"). Regiomontanus (1436–1476) was himself something of a compass-maker, and was probably the one who introduced the craft into Nürnberg.[2] Purbach seems the more promising, as Regiomontanus was only fifteen at the time the Innsbrück sundial was made. But perhaps the line on this sundial was added later, after all!

[1] Hellmann: *Die Anfänge der magnetischen Beobachtungen*, p. 113.
[2] *Ibid.*

ON THE MEASUREMENT OF LOW TEMPERATURES

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Contents.—In the first section the reader will find a general account of the methods used to determine low temperatures. The following paragraphs give these methods more in detail. Section 2 describes the cryostats; section 3 the gas thermometer; section 4 secondary thermometers, viz. the resistance thermometer and the vapour-pressure thermometer.

The special methods used in measuring the lowest temperatures are described in section 5. For the reader who is more interested in the subject, section 6 indicates a way to reduce temperature measurements to the thermodynamic scale.

§ 1. Introduction

For the progress of physics in the last fifty years it has been of great importance that the temperature range below room temperature has been made approachable for exact physical research. After the fundamental work of Wroblewski and Olszewski, who liquefied oxygen and air, Dewar invented the vacuum vessel and succeeded in liquefying hydrogen. Meanwhile Kamerlingh Onnes had taken up the systematical research of low temperatures. His attempts to liquefy helium succeeded, and so the last of the "permanent" gases had been conquered.

These new temperature ranges once reached, methods for measuring them were required. Now one of the most simple demonstrations given with liquid air is the freezing of mercury. So it is clear that the mercury thermometer will no longer be useful; at $-39°$ C. mercury is solid.

Our ordinary thermometers are based on the change of the volume of a liquid with temperature. This change of volume is shown as well by solids as by liquids, but with solids it cannot be measured exactly enough for temperature measurement. It was necessary therefore to look for another method. Such a method had already been realised in the gas thermometer.

Ideal Gas Laws. Gas Thermometer.—The law of Boyle, that the product of pressure and volume of a gas is constant if the temperature remains constant, was already long known. The behaviour of most gases, especially those that cannot be con-

densed easily, agrees very well with this law. Gay-Lussac found another not less simple law. If the pressure of a gas is kept constant, the change of the volume with the temperature is given by the law

$$v_t = v_0 \left[1 + a_v t\right] \quad (p_t = p_0).$$

If the volume remains constant, the pressure is given by the relation

$$p_t = p_0 \left[1 + a_p t\right] \quad (v_t = v_0).$$

According to the law of Boyle $a_v = a_p$. Now, the surprising result obtained by Gay-Lussac was that the value of a is the same for all gases, viz. $\frac{1}{273}$. If a gas obeys these laws it is called an ideal gas.

So a quantity of gas can be used in two different ways as a thermometer. If the volume is kept constant one can measure the pressure at the temperature which it is desired to determine. In this case we have a constant-volume gas thermometer. If the pressure at 0° C. is p_0, and at another temperature the pressure is p, the temperature is calculated from the relation

$$t = \frac{p - p_0}{a p_0} = -\frac{1}{a} + \frac{1}{a}\frac{p}{p_0} \quad . \quad . \quad . \quad (a)$$

Also a quantity of gas can be kept at a constant pressure and the temperature determined by measuring the volume. If the volume at 0° C. is v_0, the temperature corresponding to a volume v is

$$t = \frac{v - v_0}{a v_0}.$$

The thermometer used in this way is called a constant-pressure thermometer.

The determination of temperature with the aid of a gas thermometer is only correct if the gas obeys the ideal gas laws. This condition is best satisfied if the density of the gas is very small. In a constant-volume gas thermometer the density is always the same, but it is easily seen that in a constant-pressure gas thermometer the density of the gas will become very large at low temperatures. As at a high density the deviations from the laws of Boyle and Gay-Lussac become perceptible, it appears that at low temperatures a thermometer of constant volume is to be preferred to a thermometer of constant pressure. As long as the coefficient a is the same, the temperature determined in this way is independent of the kind of gas used. If, however, the accuracy of the measurements is increased, the deviations from the ideal gas laws produce a perceptible effect, and it does not remain indifferent which gas is

used. A thermometer filled with air will indicate a temperature somewhat different from that indicated by a thermometer filled with hydrogen or helium. So the question arises: Which thermometer gives the "right" temperature?

It has been a merit of Lord Kelvin to provide an answer to this question. He has shown how temperature may be defined in a manner which does not depend on the properties of any particular substance, *e.g.* of mercury, alcohol, or a gas.

In § 6 is shown how this ideal temperature can be deduced by correcting with a small amount the temperature indicated by a gas thermometer.

Substituting in formula (*a*) for a the value $\frac{1}{273}$ we have

$$t = 273 \frac{p}{p_0} - 273.$$

If the melting temperature of ice is not called 0° but 273°, we have the so-called "Kelvin scale" (° K.). Indicating the Kelvin temperature by T, we have $T_0 = 273$, and the abovementioned formula turns into

$$T = 273 \frac{p}{p_0}.$$

So if we had a thermometer filled with an ideal gas the pressure would be directly proportional to the temperature. It is striking that the temperature T = 0° is a very peculiar temperature. It is the temperature at which the pressure of an ideal gas becomes zero.

It has been shown by several scholars that this temperature can never be reached. Therefore all the attempts to reach still lower temperatures have not been made to attain the absolute zero point, but have only been made to approach this temperature as nearly as possible.

Secondary Thermometers.—In the above it has been shown that the temperature may always be determined with the aid of a gas thermometer. At low temperatures the best thing will be to fill the thermometer with a gas which condenses at a temperature as low as possible. Hence at the present helium is used almost exclusively for this purpose.

So it looks as if the problem of thermometry is solved with the construction of a gas thermometer by help of which sufficiently accurate measurements may be made.

In one of the following sections (§ 3) it will appear that accurate measurements with the gas thermometer demand much care. Hence it is of importance to be able to measure temperature by simpler methods. At present there is no other instrument which entirely replaces the gas thermometer. Any other thermometer must be compared with the gas

thermometer in a more or less direct way. These calibrated thermometers are called secondary thermometers.

In the first place the so-called "resistance thermometer" requires consideration as a secondary thermometer. As a rule the electrical resistance of a metal wire is strongly dependent on temperature. If one has a certain wire of which the resistance is known at each temperature, then one is able to determine the temperature of the wire by measuring its electrical resistance. In this article we shall not consider the methods which are used in determining the resistance.[1]

Of course the wires that are used as thermometers must satisfy very high requirements as to durability. One will thus make use of the precious metals, of which platinum renders the best service. Thermometers constructed out of platinum may be used in the temperature range from $-260°$ C. up to 660° C. As mentioned, each thermometer should be compared with the gas thermometer. However, there exists a method which does not need this comparison through the whole range.

The resistance of a wire may be represented in a formula as a function of the temperature. So in using a certain resistance thermometer, we may try to represent the temperature in a formula as a function of the resistance. Then the constants in this formula are determined by measurement of the resistance at some temperatures, which are reproduced easily (*e.g.* the freezing-point and the boiling-point of water, the freezing-point of mercury, etc.). In this way an accuracy sufficient for many purposes may be obtained.

§ 2. Cryostats

It is not only of great importance that any desired temperature may be attained, but for making accurate measurements at a certain temperature one must also be able to keep this temperature constant for some time. This may, of course, be done in several ways. A short description of the methods most used for this purpose in the Cryogenic Laboratory at Leiden will follow.

At first we will give a review of the several liquids with the temperature ranges which may be obtained with the aid of each substance.

Methylchloride	from	170° K.	to	250° K.
Ethylene	,,	140	,,	170
Methane	,,	90	,,	112
Oxygen	,,	62	,,	90
Nitrogen	,,	64	,,	77
Hydrogen	,,	10	,,	27
Helium	,,	0·8	,,	5

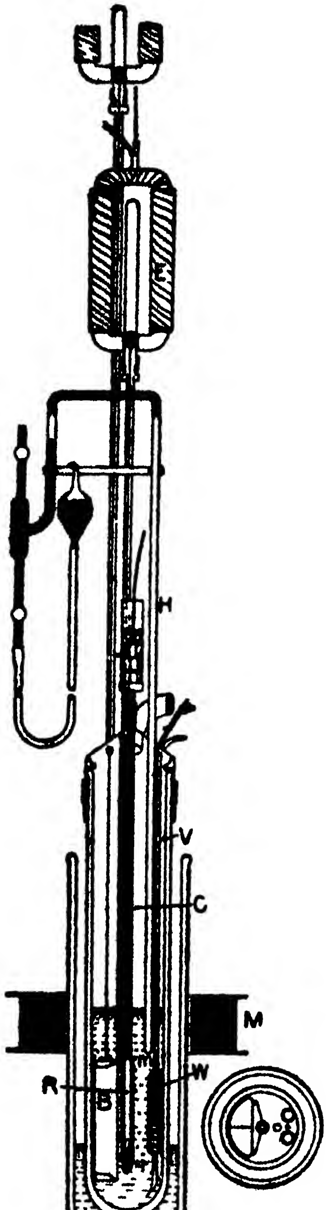

FIG. 1.—*Liquid cryostat.* B, stirrer moved by an electromagnet. W, resistance thermometer. H, "help capillary."

The range between hydrogen and oxygen is attainable by a cryostat with heated vapour of hydrogen, the range between helium and hydrogen with the aid of vapour of helium.

Liquid Cryostat.—In Fig. 1 is shown a liquid cryostat. The vacuum vessel contains the liquid. As the pressure in the cryostat must be reduced in order to vary the temperature, the top of the Dewar flask is made air-tight by a metal cap with the aid of a rubber band. To reach a certain temperature, the vapour is pumped away through the wide tube, which goes through the cap.

In this tube is placed a valve. By opening this valve the pressure, and in consequence the temperature, may be lowered. W is a resistance thermometer, which serves not only to measure the temperature but also to keep it constant. If the temperature rises the resistance increases. Now the valve is opened wider—so the pressure and also the temperature are lowered again by a small amount. In this way it is possible to keep the temperature constant within 0·01 of a degree.

It is possible that the temperature may not be uniform throughout the liquid, as the evaporation takes place almost entirely at the surface. Hence a stirrer, B, is used, which works like a pump, so that the liquid is kept in permanent circulation. The stirrer is moved with the aid of an electro-magnet which draws a piece of soft iron up and down. If the cryostat contains liquid hydrogen, it is placed in another vacuum vessel, which contains liquid air. This to pre-

vent hydrogen from evaporating too quickly. The helium cryostat is surrounded by two of these vessels. The inner contains liquid hydrogen, the outer liquid air.

Vapour Cryostat.—The vapour cryostat consists of two vacuum vessels. The first contains the liquid. This liquid is quickly evaporated, and the vapour is led into the second vacuum vessel.

By means of a heating coil the vapour is brought to the required temperature. It then passes into the experimenting chamber which has been placed in the same vacuum vessel. The regulation of the temperature occurs automatically. For this purpose a small gas thermometer is placed in the apparatus. If the temperature of the inflowing vapour is too high, the pressure in the gas thermometer increases. By this a mercury meniscus is moved, and so the heating current is switched off. The temperature now falls, the electrical current is switched on again, and the vapour is heated as before.

A cryostat, as described, may in principle be used with any liquid. At Leiden the hydrogen-vapour cryostat was often used. It gives a constancy of temperature of 0·02 of a degree. Further there is no difficulty in using this method for the helium-vapour cryostat, except that considerable quantities of liquid helium are needed, which make the method not very economical.

Hence we try to reach this temperature range in another way.

For particular purposes other types of cryostats are often used.

§ 3. The Gas Thermometer

The gas thermometer is used in many different models. In this article we shall confine ourselves to a description of a gas thermometer especially adapted to the measurement of low temperatures, used at Leiden in the Cryogenic Laboratory.[3]

In the introduction it was stated that the gas thermometer with constant pressure is not suited for low-temperature measurement, the density of the gas increasing more and more at low temperatures. Now it is not possible to construct a thermometer with a volume always remaining the same. In the first place, there will be no reservoir that does not alter its volume with temperature.

Moreover, for measuring the pressure it will be difficult to avoid that part of the volume—of course as little as possible—is at room temperature.

A view of the gas thermometer is given in Fig. 2. The bulb T is placed in the space of which the temperature is to be determined.

The connection of the bulb and the manometer is formed by a glass capillary about 50 cm. long, in which the transition of the low temperature to room temperature takes place; and further by a steel capillary. By this capillary the bulb is freely movable.

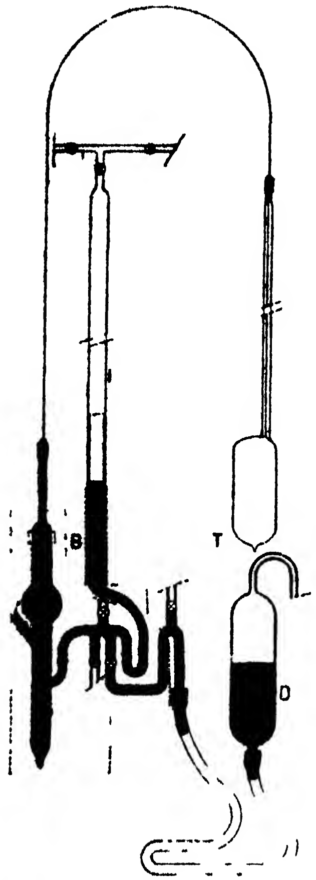

FIG. 2.—*Gas thermometer* T, bulb of the thermometer connected to the manometer with a glass capillary, followed by a steel capillary. B, steel point for the adjustment of the mercury meniscus. D, mercury reservoir.

In the short leg of the manometer is put a steel point, B. At the measurement the mercury is brought near to this point by means of the movable mercury reservoir, D. The different tubes between D and the manometer are constructed so that the air the mercury may take with it is prevented from entering the reservoir.

The space above the mercury in the long leg of the manometer is evacuated. For measuring higher pressures, however, it is connected to a barometer.

For the determination of a temperature we must know: (1) the pressure of the gas, and (2) the volumes and temperatures of those parts of the gas that are not in the bulb (the noxious volume).

The height of the mercury column in the manometer is determined with the aid of a cathetometer or a comparator. To this value of the pressure several corrections must be applied. The density of the mercury must always be reduced to the density at 0° C. So we have to know the temperature of the mercury. Also the corrections for the capillary depression of the mercury menisci must be known.

In the second place the temperature of the steel capillary and of the volume at B must be determined. The corresponding volumes are measured beforehand. The volume of the mercury meniscus is derived from a formula. It is more difficult to determine the temperature of the glass capillary. This is made possible by an invention of Chappuis. Next to the glass capillary a glass tube is mounted, filled with gas, whose pressure is

measured. In the cryostat of Fig. 1 such a "help capillary" is shown. The mean temperature of this tube, the pressure being p, is calculated from—

$$t = \frac{p - p_0}{ap_0}.$$

Finally the volume of the reservoir at the temperature $t°$ is not the same as at 0° C. This for two reasons—the pressures in and outside the thermometer have changed, and hence the reservoir will be compressed or dilated. This elastic change will only give very small corrections. The more important cause is the thermal expansion of the reservoir.

Generally the reservoir is made of glass. For most sorts of glass used for this purpose the thermal expansion coefficient is already known. Difficulties arise, because glass is not always an absolutely defined substance. Samples of the same sort of glass, prepared in a different way, often show differences in expansion coefficient.[4]

Calculation of the Corrected Pressure.—As the pressure of the gas thermometer, we will take the pressure the gas would have if all the gas were in the bulb, the bulb itself having the same volume as at 0° C. This pressure may be calculated in two steps. First we calculate the volume the gas would have if all its parts were brought at the temperature of the bulb, while the pressure remains constant. This may be done with the aid of the law of Gay Lussac. In the second place we compress this volume till it has reached the value V_0, the volume of the bulb at 0° C. The pressure obtained in this way we call p. When the pressure at 0° C., determined in the same way, is p_0, the temperature is derived from

$$t = \frac{p - p_0}{ap_0};$$

where a is the mean pressure coefficient of the gas between 0° C. and 100° C.

$$a = \frac{p_{100} - p_0}{100\, p_0}.$$

Accuracy of the Gas Thermometer.—The accuracy of the gas thermometer is limited by the accuracy of the determination of the pressure and the uncertainty in the noxious volume and the thermal expansion. When the pressure is read with a cathetometer or a comparator, the error may be about 0·02 or 0·01 mm. The relative error could be made very small by taking the zero-point pressure sufficiently high, but it is not easily possible to determine with these instruments pressures much above 1,000 mm. mercury. If this pressure is chosen, a change of one

degree in the temperature gives a corresponding variation in the pressure of 3·6 mm.

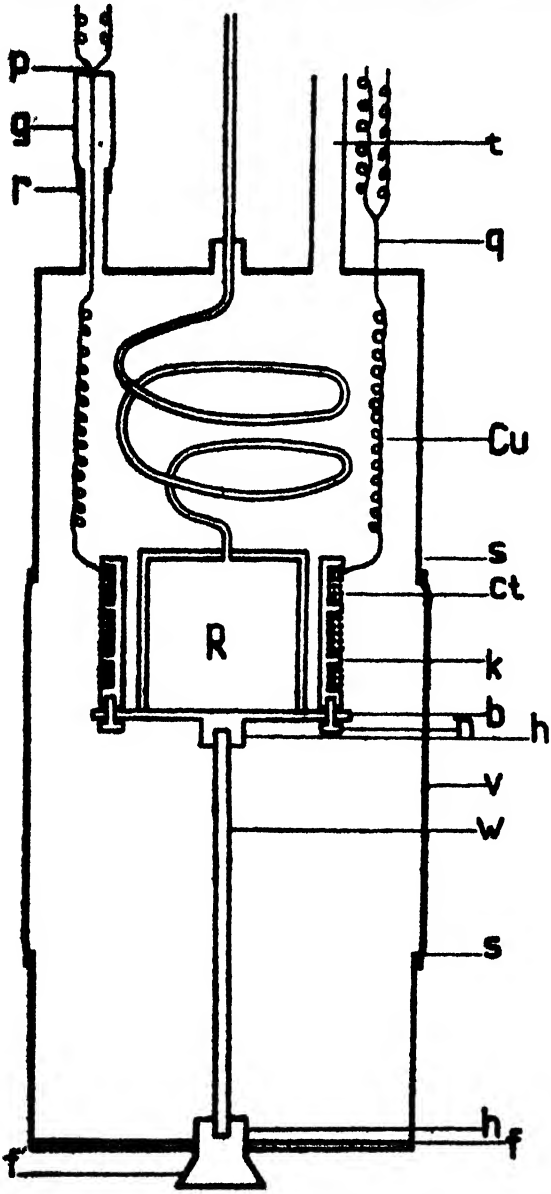

FIG. 3.—*Gas thermometer used for measuring thermal conductivity.* W, rod of which the conductivity is to be measured. R, bulb of the thermometer. Ct, heating coil. *t*, tube connected to a vacuum pump.

The accuracy of the corrections for the noxious volume is determined by the accuracy with which the ratio of $\frac{v_n}{V_o}$ (v_n = noxious volume) is known. Moreover, the influence of these corrections is much more at higher temperatures, and at hydrogen temperatures it may almost be neglected. Though the volumes of the capillary, etc., are known well enough, the volume at B is different at each measurement, and cannot be determined exactly. If the volume of the reservoir is about 100 c.c., an error of 3 c.mm. in the v_n will give an error in the determination of temperature of 0·01°. This accuracy might be increased by increasing the volume V_o, but in that case it becomes difficult to have always a uniform temperature around the reservoir.

A determination of *a* can be carried out with each separate thermometer. At temperatures above 0° C., however, the influence of the noxious

volume increases very much. So these determinations need many precautions.

At lower temperatures, on the other hand, this correction becomes very small, and the accuracy is only limited by the errors in the pressure. The value of a, and the thermal expansion of the glass once known, an accuracy of 0·01° in temperature determination may be reached.

Other Forms of the Gas Thermometer.—The gas thermometer as described here is only used for testing secondary thermometers, the accurate determinations of boiling-points, etc. Especially at lower temperatures it becomes possible to use thermometers with a small reservoir, without any loss of accuracy, as the errors caused by the noxious volume have only a small influence.

Fig 3 represents an apparatus used for measuring the thermal conductivity of a rod, W.[5] In the evacuated chamber is a heating coil and a gas thermometer. The temperature of the upper end of the rod is determined with the gas thermometer, whose volume is only a few c.c.; the lower end is at the temperature of the bath.

For the calculation of the temperature from the pressure, p_0 would be wanted. It is possible, however, to take the boiling-point of helium (4·2° K.) or of hydrogen (20·4° K.) as a basic point.

§ 4. Secondary Thermometers

We have mentioned already the possibility of measuring the temperature in a more indirect way. Once it is known how the resistance of a metal wire, the vapour pressure of a liquid, etc., depend on temperature, one may use the measurement of these quantities to determine the temperature. Such indirect thermometers are called secondary thermometers. Especially at low temperatures, the resistance thermometer and the vapour-pressure thermometer are used.

Resistance Thermometers.—The resistance of most of the pure metals depends rather in the same way on temperature, as is shown in Fig. 4. At room temperature and lower the resistance is almost a linear function of the temperature, but still lower, the curve becomes more and more horizontal. Below the temperatures that are obtainable with liquid hydrogen (10° K.), the resistance becomes practically constant. At these temperatures a resistance thermometer is no longer useful; small variations in temperature will no longer cause measurable variations in the resistance.

Alloys often show quite different resistance temperature curves. At the lowest temperatures some alloys can be used as resistance thermometers (*cf.* § 5).

The metals which are used for resistance thermometers are

platinum, gold, and lead. *They do not change under influence of air or humidity, and can be produced rather pure.*

Even if the wire is not subject to external influences, there may be internal causes which produce change in its resistance. A metal is composed of very small crystals, and the size and shape of these crystals have a considerable effect on the resistance of the metal when a stable arrangement of the crystals is attained; a change in temperature or a tension in the wire

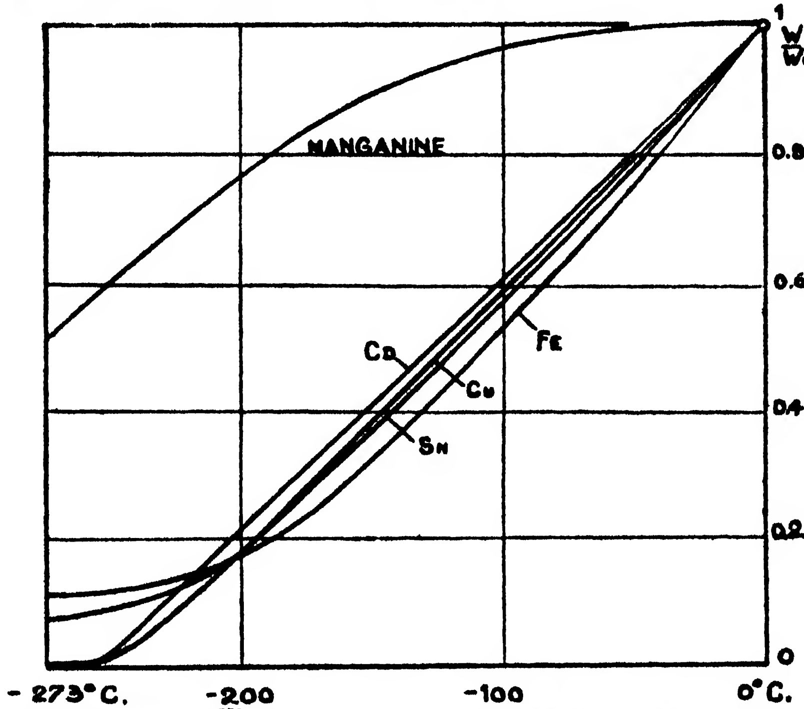

FIG. 4.—Resistance $\left(\frac{W}{W_0}\right)$ of copper, iron, tin, and manganin as a function of the temperature. The resistance of the metal is divided by its resistance at 0° C.

may cause alterations in them, and so in the resistance. For instance, the resistance of a wire of mercury enclosed in a glass capillary was measured. Every time the mercury was re-solidified it showed another resistance, caused by a different arrangement of the crystals.

The preparation of pure and constant resistance wires has best succeeded with platinum, though even here the variations have not disappeared entirely. However, some resistance thermometers have been constructed whose resistance at 0° C. has remained constant for several years within $\frac{1}{15,000}$ of its value.

Construction of the Resistance Thermometer.—The wire is coiled up on a grooved porcelain tube or on a mica cross. It must be absolutely free from tensions, not only at room temperatures, but also at lower ones, when the wire contracts more than the tube.

To reach a stable crystallisation of the wire, the whole thermometer must be annealed for some hours at a temperature of about 800° C. So will the wire adapt itself to its new shape.

The resistance thermometer has, in many cases, advantages over the gas thermometer. Small temperature differences may be determined with it even more accurately. Moreover, it follows rather quickly the variations in temperature of the bath, and by its small dimensions it can easily be mounted in small cryostats. The gas thermometer requires much more space and more precautions during the measurement.

Testing of the Resistance Thermometer.—The usefulness of the resistance thermometer would be very much increased if it were possible to prepare wires of an absolutely pure metal crystallised in a known way. In that case it would be sufficient to determine the resistance of one of these wires as a function of the temperature, knowing it then for all the others. Unfortunately, very small impurities in a metal can cause a considerable increase of the resistance. It is therefore necessary to determine the resistance-temperature curve for each thermometer separately. These determinations are made with the aid of a gas thermometer, measuring at each temperature the corresponding resistance, with intervals of some degrees, through the whole range.

When this comparison must be carried out with much accuracy it is a long and rather difficult task; and especially for those laboratories which are not adapted for exact determinations with the gas thermometer this is a serious difficulty.

The differences shown by the resistance curves of several platinum thermometers are not quite irregular. So we can hope that these deviations may be characterised by a few constants. In that case it would suffice to determine the resistance at a few temperatures that can easily be reproduced, and to calculate from these values the constants that fix the resistance curve of the thermometer.

International Temperature Scale [6].—According to measurements of Callendar, the resistance of a platinum wire can be represented from 0° up to 660° C. by the formula

$$R_t' = R_0 (1 + at + bt^2).$$

(R_t = resistance at t° C., R_0 = resistance at 0° C.) The constants a and b may be calculated by measuring the resistance at the boiling-point of water and at the boiling-point of sulphur

(444·60° C.). For lower temperatures a formula of this form no longer gives a good result; from 0° C. to − 190° C. we can try to represent the experimental results by adding the term $ct(t-100)^2$. The constant c, again, may be determined by measuring the resistance at the boiling-point of oxygen (− 182·97° C.). Before such a formula can be applied to each thermometer, it must be tested several times with different thermometers. The first results of this testing appeared to be sufficiently encouraging to define the "international temperature scale" with the aid of the resistance of a thermometer made from sufficiently pure platinum. So if one has determined in the above-mentioned formula of Callendar the constants R_0, a and b, by measuring the resistance of the thermometer at the melting-point of ice, the boiling-point of water, and the boiling-point of sulphur, and also the constant c with the aid of the boiling-point of oxygen, this formula will give the temperature on the international scale.

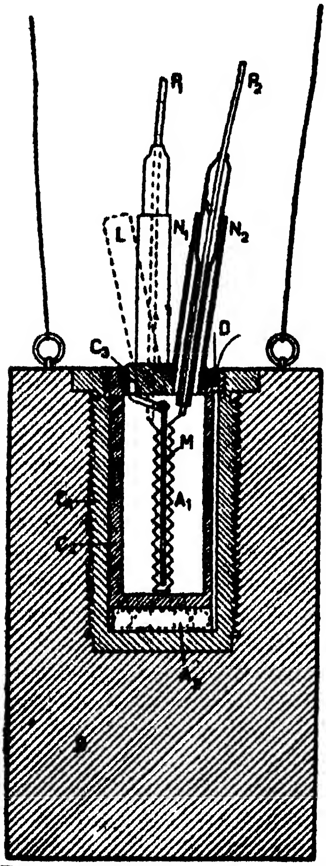

FIG. 5.—*Resistance thermometer used for measuring heat capacities.* B, block of which the heat capacity is to be measured. A_1, resistance thermometer mounted on a mica blade M. A_2, heating coil.

This scale, however, does not permit of the same precision as direct determinations with the gas thermometer. If the temperature is calculated from the resistance, it may differ 0·05° from the temperature measured directly.[7] Although these deviations give a warning that this procedure is not yet developed sufficiently well to serve as a fundamental temperature scale, this simple method of temperature determination may be useful in many cases.

Particular Constructions of the Resistance Thermometer.—Not only does the resistance thermometer render good service in determining the temperature of liquid baths, but it is also possible to use it for special purposes, by its very simple form. As an example, in Fig. 5 is given a model of a calorimeter used for determinations of the specific heat of solids. The block B,

whose heat capacity is to be measured, is suspended in a space which can be evacuated, and so the block is insulated. The increase of temperature, obtained by putting a current through the heating coil A_2, is measured with the resistance thermometer A_1, whose dimensions amount only to 1·5 cm. Of course the conducting wires to the thermometer must be insulated from the metal. Therefore these wires are fused in glass tubes, which are again fastened to the calorimeter with sealing-wax. If the space M is filled with a small quantity of helium gas, one may be sure that the thermometer indicates the temperature of the block quickly enough.

Vapour-pressure Thermometers.—The vapour pressure of a substance may often be used for determining the temperature. The advantage of this method is that it is quite reproducible, if only sufficiently pure substances are available. So one does not depend, as in resistance thermometry, on all kinds of influences which change the resistance and cannot easily be controlled.

The vapour-pressure thermometer is only useful over a rather small range; for instance, the vapour pressure of hydrogen is easily determined only from 20° K. to 11° K. At higher temperatures the vapour pressure increases very rapidly; at lower temperatures it becomes too small to be easily measured. A vapour-pressure thermometer of the type used at Leiden is shown in Fig. 6. It consists of a small bulb connected with a copper capillary to the manometer tube. The bulb is filled through the tube *t*, and at room temperature the gas is also in the wider part of the tube *m*. When making a measurement the gas is compressed

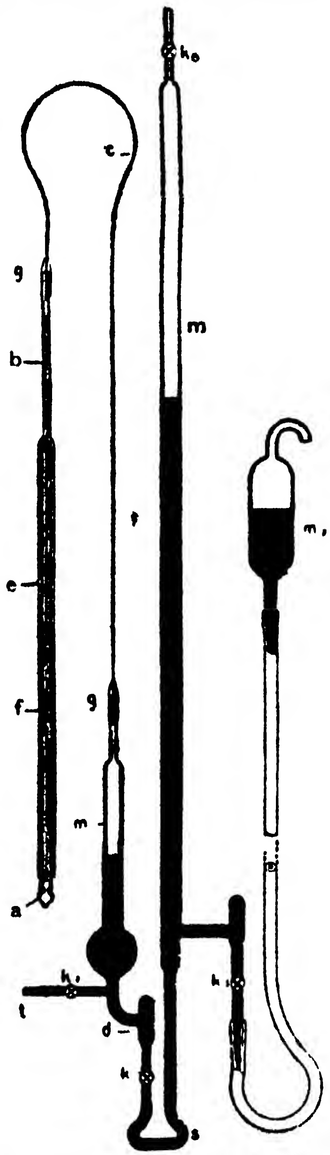

FIG. 6.—*Vapour-pressure thermometer.* *a*, small bulb containing the liquid *e* and *f*, tubes of copper and glass, surrounding the capillary *b* *m*, short and long legs of the manometer.

by the mercury until it condenses in the reservoir *a*. The reservoir, with a part of the glass tube, is in the liquid bath. As it is possible that by the evaporating of the liquid the upper layer is the coldest, the tube may not be in direct contact with this layer. Therefore the tube is first surrounded by copper, and this copper tube again by a glass tube closed at the upper end. In this way the coldest place of the tube is at the lowest end, and so the gas will condense there. To prevent the radiation from above affecting the reservoir, the tube is bent near the reservoir.

Especially for reproducing some fixed temperatures the vapour-pressure thermometer renders good service. As for instance, for the boiling-points of oxygen and hydrogen. In cryostats with liquids it is often possible to determine the temperature directly from the pressure of the bath.

§ 5. Temperatures Obtainable with Liquid Helium

Kamerlingh Onnes succeeded in liquefying helium on July 10, 1908. This was of course of great importance for the Leiden Cryogenic Laboratory, for an extraordinarily interesting temperature range became approachable for measurements.

A short time thereafter a temperature of 1·15° K. was reached by rapidly pumping away the vapour above the liquid helium. The corresponding vapour pressure was about 0·2 mm.

In 1921 Kamerlingh Onnes made an attempt to obtain still lower temperatures.[8] For this purpose a specially constructed small Dewar glass was used which had a volume of only a few c.c. In order to reduce the heat, conveyed to the evaporating helium, as much as possible, the small Dewar glass was placed in a surrounding Dewar glass, which was also filled with liquid helium.

The vapour above the liquid in the small Dewar glass was pumped away by a complex of eighteen Langmuir condensation pumps with which the vapour pressure could be reduced to about 0·02 mm. A provisional determination of the temperature corresponding to this pressure was made by extrapolating the vapour-pressure curve of liquid helium. In this way the lowest temperature obtained was determined to be about 0·82° K. Even at this temperature the liquid helium did not become solid.[1]

Thermometry.—In a former section it was shown how the temperature could be determined by means of a gas thermometer.

[1] On February 17, 1932, a still lower temperature was reached. Prof. Keesom succeeded in obtaining a temperature of 0·71° K. in 5 c.c. of helium. The lowest pressure of the helium was 0·0036 mm.

Therefore measurements of temperature in this range must also be made with this thermometer filled with helium gas. Now several difficulties arise. To prevent the gas in the thermometer from showing large deviations from the ideal gas law, the pressure must be very small. At this low pressure a phenomenon makes its appearance, which gives rise to very large corrections in the pressure measurements. This phenomenon is the thermomolecular pressure difference.

The Thermomolecular Pressure Difference [9].—If the ends of a tube, filled with gas, differ in temperature, there can, in the case of equilibrium, also be a pressure difference between those ends. This pressure difference depends very much on the ratio of the diameter of the tube R to the mean free path of the gas molecules λ.

Two limiting cases are possible. If p_1 and p_2 are the pressures, T_1 and T_2 the temperatures at the different ends of the tube, we have—

$$(1)\ \frac{p_1}{p_2} = \sqrt{\frac{T_1}{T_2}} \qquad \text{if } R << \lambda$$

$$(2)\ p_1 = p_2 \qquad \text{if } R >> \lambda$$

For intermediate cases a more complicated formula can be derived (see *Communications of the Physical Laboratory*, Leiden, No. 147*b*). This formula contains some constants which could not be derived theoretically. It was brought into agreement with the experiments by measurements at the boiling-points of liquid oxygen, 90·12° K., and of liquid hydrogen, 20·33° K. Then it was applied to the measurements at the lowest temperatures.

The Hot-wire Manometer.—As the pressure in the gas thermometer is very low, a mercury manometer cannot be used for measuring the pressure. An apparatus which is suitable for the measurement of low pressures is the hot-wire manometer. It consists of a thin metal wire which is stretched in a reservoir. The wire is heated by an electrical current. The heat developed by the current is transported by the gas to the walls of the tube, which are kept at a constant temperature. Now, for small pressures the thermal conductivity of the gas is proportional to its pressure. Hence the current needed to heat the wire up to a fixed temperature must be larger if the pressure of the gas is larger. So the pressure can be measured by determining the electrical current in the wire. The temperature of the wire is fixed by measuring the electrical resistance. Of course this manometer must be calibrated beforehand at known pressures.

Vapour-pressure Curve of Helium.—A convenient way to measure the temperature of a helium bath is to determine the vapour pressure.

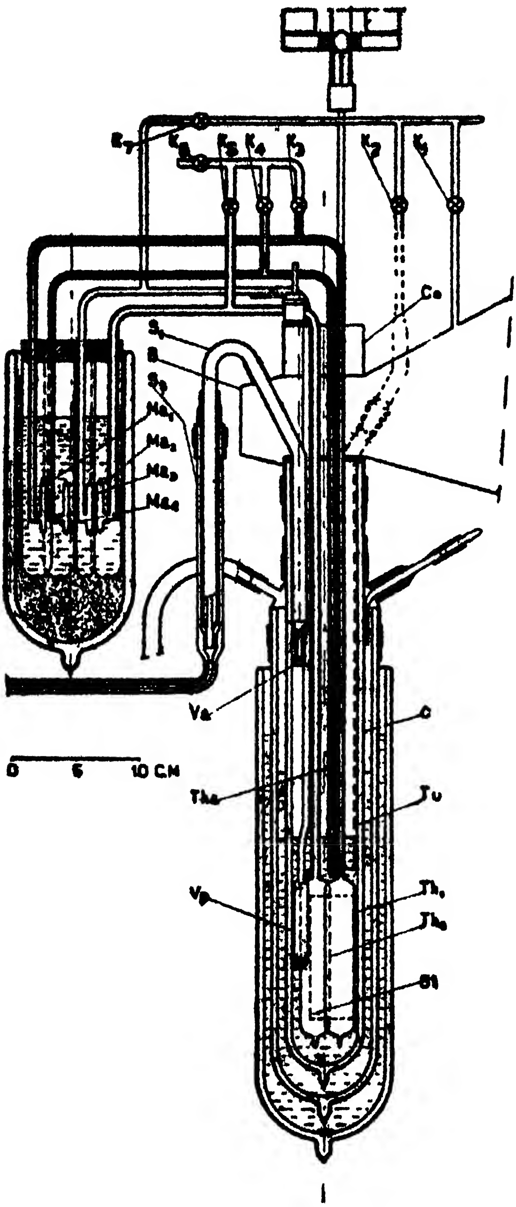

FIG. 7.—*The vapour-pressure of helium.* Th_1 and Th_2 gas thermometer bulbs, connected with the hot-wire manometers Ma_1 and Ma_2. V_p, vapour-pressure thermometer, connected with the hot-wire manometer Ma_3. S_1, filling tube of the helium flask. The upper end of this flask is connected with the pump.

From this the temperature may be derived if the relation connecting vapour pressure and temperature is known. For determining the vapour-pressure curve, measurements with a gas thermometer are necessary. To contain the necessary measuring apparatus the cryostat must have a volume of about 300 c.c. To reach the temperatures below 1° K., it is necessary to employ a pump with a great capacity. For this purpose two very large diffusion pumps were specially constructed. If connected in parallel, they have an exhaust capacity of 675 litres of helium per second. Making use of these pumps, it was possible to obtain in the already mentioned space of about 300 c.c., a temperature of about 0·85° K.

Fig. 7 gives a detailed review of the apparatus with which measurements of the vapour-pressure curve have been made. [10] The helium cryostat is placed in a Dewar glass with liquid hydrogen. In its turn this vessel is surrounded by another

filled with liquid air. Th_1 and Th_2 are the reservoirs of two thermometers filled with helium gas. Th_3 is the tube of the "help capillary," which serves to determine the corrections for the noxious volume of the gas thermometer. Tu is an open tube reaching into the liquid. Vp is the reservoir of a vapour-pressure apparatus.

Th_1, Th_2, Th_3, and Vp are separately connected with hot-wire manometers (Ma_1, Ma_2, Ma_3, and Ma_4). These manometers are kept at a constant temperature by placing them in a Dewar flask filled with melting ice. The top of the helium cryostat is connected directly with the large-diffusion pumps. By means of the tubes S_1 and S_2 the cryostat can be filled with liquid helium. This is the apparatus with which the temperature measurements have been made.[11]

The vapour pressures were determined in the tube Tu and in the vapour-pressure apparatus, which was half filled with liquid helium.

It appeared that, at the lowest temperatures, the pressure measured in Tu was lower than that measured in Vp. Probably this difference was caused by the fact that, in spite of permanent stirring the uppermost layer of the liquid, in consequence of the quick evaporation, had a somewhat lower temperature than that measured by the two thermometers. Moreover, it is clear that at low pressures the hydrostatic pressure difference produces an appreciable effect.

Several corrections had to be applied to the measurements. The most important was the correction for the thermomolecular pressure difference. It was calculated by means of the formula already mentioned. The corrections on account of the deviations of helium from the ideal gas law amounted at the utmost to only one in one thousand and so could be neglected.

Secondary Thermometers [12].—The platinum resistance thermometer, which renders excellent services as a secondary thermometer in a wide temperature range, cannot be used at the temperatures of liquid helium, as in this range the resistance of platinum remains practically constant. However, it is of importance to be able to measure the temperature with a resistance thermometer.

At the outset wires of constantan and manganin were used for this purpose. In this temperature range these alloys have a sufficient change in resistance to be used for thermometric measurements. In a magnetic field, however, their resistance shows a relatively large change. This change does not entirely disappear if the magnetic field is switched off.

For that reason the resistances of several metals and alloys were examined. It appeared that phosphor-bronze was very suitable for use as a secondary thermometer. The temperature

coefficient of the resistance was about fifty-five times as large as for constantan. Moreover, the resistance depends in a nearly linear way on the temperature. The influence of a magnetic field appeared to be relatively small and did not cause a lasting disturbance. After the phosphor bronze thermometer had been calibrated by making use of the vapour-pressure curve of liquid helium, it was used for the determination of temperature in further investigations.

§ 6. Reduction of the Scale of the Gas Thermometer to the Thermodynamic Scale [13], [14]

In the preceding paragraphs it was pointed out that the indications of two gas thermometers will differ somewhat if the pressures of the gas in them are not the same at the same temperature.

For an ideal gas $pv = A$, where A only depends on temperature.

For a real gas this is only an approximation. When the density is not too high, however, we may write—

$$pv = A + \frac{B}{v} \quad . \quad . \quad . \quad (1)$$

In this formula A and B are both functions of the temperature; p is the pressure of the gas; v is the specific volume (reciprocal density) of the gas.

Now we will compare the indications of two thermometers, filled with the same gas; the first filled to an ordinary density, but the second with so small a density that we may always neglect the term $\frac{B}{v}$ in (1).

The temperature of a gas thermometer is defined by—

$$t = \frac{p_t - p_0}{a p_0}, \text{ where } a = \frac{p_{100} - p_0}{100\, p_0} \quad . \quad . \quad (2)$$

Substituting for p its value, given by (1) (v always remaining the same)—

$$t_v = \frac{A_t - A_0 + \frac{B_t}{v} - \frac{B_0}{v}}{a A_0 + a \frac{B_0}{v}}, \text{ and} \quad . \quad . \quad (3a)$$

$$a_v = \frac{A_{100} - A_0 + \frac{B_{100}}{v} - \frac{B_0}{v}}{100\left(A_0 + \frac{B_0}{v}\right)} \quad . \quad . \quad (3b)$$

For the thermometer with small density these formulæ become—

$$t = \frac{A_t - A_0}{a\, A_0} \text{ and } a = \frac{A_{100} - A_0}{100\, A_0} \quad . \quad . \quad (4)$$

The difference in the indications of the two thermometers is therefore—

$$t_v - t = \frac{B_t - B_0}{a\, v} - \frac{t_v}{a}\,\frac{B_{100} - B_0}{100\, v} \quad . \quad . \quad (5)$$

(terms containing $\frac{1}{v^2}$, are neglected).

In this way it is possible, when B is known as a function of the temperature t_v, to reduce the determinations of a gas thermometer to the scale of a thermometer with very small density. This scale is called the *Avogadro scale* of the thermometer.

Summary :

1. The scale of the gas thermometer, defined by (2). This scale depends on the kind of gas and its density.
2. The Avogadro scale, defined by (4). This is the scale of a gas thermometer with a very small density of the gas. The difference between these two scales are given by (5).
3. Finally we have the thermodynamic scale that is based on the second law of thermodynamics.

The assumption is made, that the *Avogadro scales of all gases are the same*, and *coincide with the thermodynamic scale.*

Differential Thermometer.—The first part of the last-mentioned assumption can be verified experimentally. This may be done by means of the differential gas thermometer.

This thermometer is a combination of two thermometers of the type given in Fig. 2. These two thermometers have in common a long leg of the manometer. One of the short legs of the manometer can be adjusted so that it is possible to determine the pressure in both thermometers at the same time.

One of the reservoirs is filled, for instance, with helium, the other with hydrogen.

This apparatus is very suitable for registering differences in the temperature indications of both thermometers. The errors in the noxious volume can be eliminated by exchanging the fillings of both thermometers, while almost all the possible errors that may occur in the temperature of the mercury, etc., will be the same for both thermometers.

In Fig. 8 is given the result of some measurements with the

differential thermometer.[15] These measurements have not only been performed at different temperatures, but also for different densities of the gas in the thermometers. From these results it appears that the differences in indications of both thermometers $(t_{He} - t_{H_2})$ decreased with decreasing density

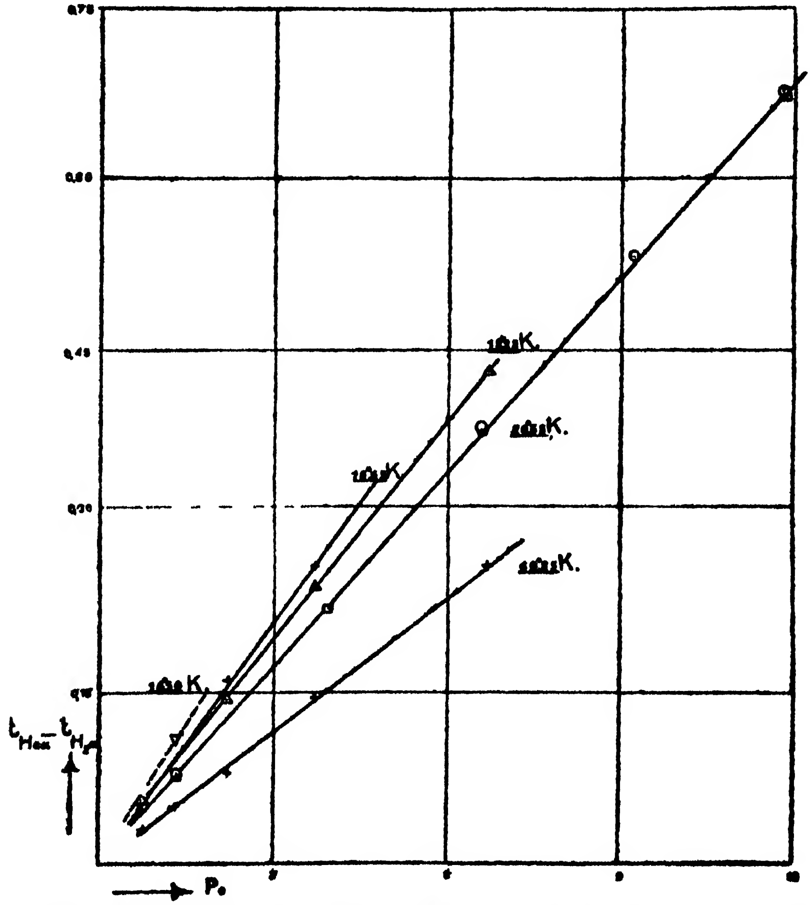

FIG. 8.—Differences of the indications of a helium and a hydrogen thermometer $(t_{He_a} - t_{H_2a})$ as a function of the pressure of the gas at 0° C.

according to (5). This difference becomes zero when we extrapolate the density to zero.

So the result is: The Avogadro scales of the helium and hydrogen thermometer coincide for these temperatures. In this way the first assumption can be tested. The second assumption cannot be tested so directly. It is possible to deduce it theoretically from the kinetic theory of gases.

Finally, I should like to thank Prof. W. H. Keesom for his kind help in the preparation of this article.

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NOTES

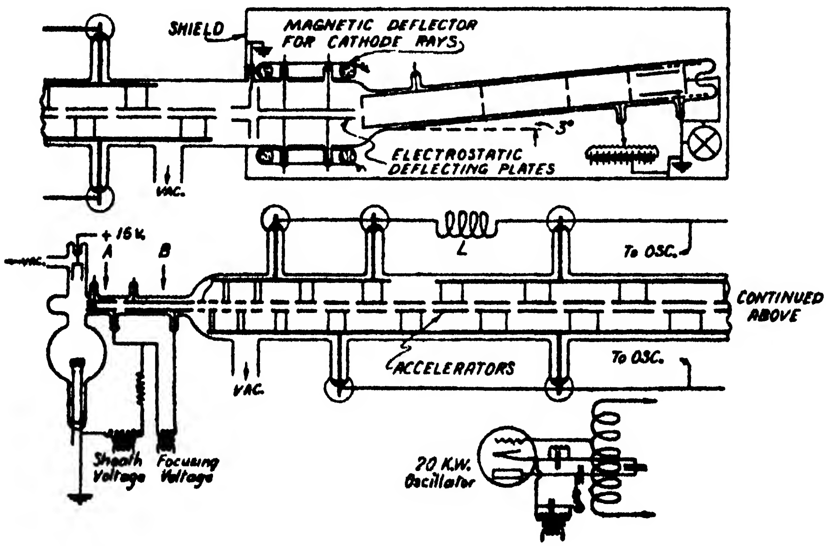
HIGH-SPEED IONS PRODUCED WITHOUT EMPLOYING HIGH VOLTAGES (F. H. L.)

High-speed things—electrons, protons, neutrons ?, ions and atoms—are engaging the special attention of men of science in many laboratories of the world. Great progress has already been made in the generation of high-speed electrons and of high-speed ions, particularly by means of specially constructed vacuum-tubes. Naming those who have made remarkable progress in recent years, there are : W. D. Coolidge (*Am. Inst. El. Engrs.*, 1928, **47**, 212) ; C. C. Lauristen and R. D. Bennett (*Phys. Rev.*, 1928, **32**, 850) ; M. A. Tuve, G. Breit, and L. R. Hafstad (*Phys. Rev.*, 1930, **35**, 66) ; A. Brasch and J. Lange (*Zeits. f. Physic*, 1931, **70**, 10) ; J. J. Cockroft and E. T. S. Walton (*Proc. Roy. Soc.*, 1930, A **129**, 477) ; R. J. Van de Graaff (Schenectady meeting of the American Physical Society, 1931). These investigators and their collaborators have been able to reach voltages of the order of one million, but to exceed this voltage up to, say, 10,000,000, is an accomplishment beset with experimental difficulties. In addition, such high voltages involve " apparatus quite beyond the equipment of most physical laboratories and are somewhat cumbersome for detailed experimental investigations of the types that have been carried out in the range of low voltages "—to quote the words of D. H. Sloan and E. O. Lawrence in the *Physical Review* (December 1, 1931, **38**, 2021–32) in a paper describing the production of heavy high-speed ions without the use of very high voltages.

In the laboratory of these investigators three methods are being developed : (1) production of high-speed electrons by a method discussed at the Pasadena meeting of the American Physical Society in June 1931 ; (2) a method designed for the acceleration of relatively light ions (E. O. Lawrence and N. E. Edlefsen, *Science*, 1930, **72**, 376 ; E. O. Lawrence and M. S. Livingston, *Phys. Rev.*, 1931, **38**, 834) ; (3) a method, the fundamental principle of which was experimentally demonstrated by R. Wideroe (*Arch. f. Electrotech.*, 1929, **21**, 387), forming the subject-matter of the paper above referred to, by Sloan and Lawrence, which is briefly described here. These investigators

had, in their initial experiments, obtained high-voltage mercury ions (*Proc. Nat. Acad. Sci.*, 1931, 17, 64), but much higher ion-voltages are now obtainable, as will appear presently. In speaking of " high-voltage ions " high speeds are implied.

According to this method a series of copper tubes (5 mm. diameter) are mounted co-axially in a vacuum tube. These copper tubes are made successively longer by approximately the square roots of integers times the length of the first tube as diagrammatically shown in the accompanying figures.



The ions to be accelerated pass along the common axis of these tubes which are connected alternately to a high-frequency oscillator. " A high-frequency voltage applied in this manner produces at any instant electric fields between successive accelerator tubes of opposite direction and equal magnitude. If at one instant an ion finds itself between the first and second tubes with the field in the right direction it will be accelerated into the second tube, and if the time consumed in passing through this tube is equal to the half period of the oscillating field, it will arrive between the second and third tubes with the field reversed in direction in such manner that it will receive additional acceleration on passing into the third tube," and so on. The tubes are made of increasing lengths, as stated above, so as to synchronise the operation and raise the energy of the ions. " Thus, for example, in the present experimental tube 42,000 volts applied to the 30 accelerators resulted in the production of ions [singly charged Hg ions] having kinetic energies corre-

sponding approximately to 30 times 42,000 volts, *i.e.* 1,260,000 volts," the current being 10^{-7} amp.

It is to be noted that the ions generated in a hot-cathode tube, as shown at the left-hand side of the diagram, are drawn out symmetrically and then brought to a focus centrally in the system, by using tubes A and B, as shown. The latter tube is closed in a little at the right-hand end. Separate voltages are applied, as shown in the diagram, to bring about this result. To assist in synchronising the ion movements with the oscillating field, a single loading coil, L, is used for the first ten accelerators.

It is stated that with one oscillatory circuit the number of accelerators is limited by the capacity of the system, but with several oscillators in parallel, connected with separate groups of accelerators, it should be possible to work up to 10 million volts. It is estimated that this voltage can be attained with singly charged Hg ions, the accelerating system then being 40 feet long and fed by eight power amplifiers in parallel.

High-velocity Protons (L. F. B.)

A source of protons which have been made to traverse a fall of potential of over 1 million volts, without the use of a high-voltage supply, has been described by E. O. Lawrence and M. S. Livingston (*Phys. Rev.*, **40**, 19, 1932), and the authors expect that it will be possible, by reasonable extension of their equipment, to produce ions with a drop of 25 million volts. The method of production consists in making the same beam of ions traverse a fall of potential of some 4,000 volts many times in succession, so that finally the beam possesses an energy corresponding to a fall through a very large potential difference.

Semi-circular hollow plates very similar to the duants of an electrometer, are mounted in a vacuum with their diametrical edges opposite and close to each other. A magnetic field is applied normal to the plane of the plates. The latter form the electrodes to which a high-frequency supply from a 20-kilowatt water-cooled power tube is connected, so that an oscillating electric field is established in the diametrical region between the plates. Let us now suppose that positive ions are produced in this region by collision of gas molecules with a beam of electrons from a heated filament. Then, during one half of the cycle these ions will be accelerated by the field into the interior of one of the electrodes, where they will be bent into circular paths under the influence of the magnetic field, and thus eventually return to the region between the electrodes.

It is clear that the magnetic field may be so adjusted that the time the ions spend inside the electrode is exactly equal to

one half period of the oscillating electric field. Hence, on emerging into the diametrical space they will find the field between the electrodes reversed, and accordingly they will move into the other electrode. It must be observed, however, that in their passage across the diametrical region they again receive another increment of velocity as they fall through a difference of potential once more.

The radii of the paths described within the electrodes are proportional to the velocities of the ions, and therefore the time an ion spends inside the electrodes is independent of its velocity. Hence, once the magnetic field is correctly adjusted for this time to be equal to one half period of the electrical supply, the magnetic field is able to secure the passage of the ions across the diametrical region at an auspicious moment on all the future occasions when they arrive in the space between the electrodes. Consequently, the ions describe spiral paths in resonance with the electrical supply, until, at last, they reach the confines of the apparatus with kinetic energies very much greater than that corresponding to a single transit across the diametrical region; in fact, equal to the latter energy multiplied by the number of transits, which may be some hundreds.

The success of the Lawrence and Livingston apparatus is greatly due to the focusing actions of the electric and magnetic fields. Indeed, the focusing actions are so powerful that beams of high-speed protons are obtained with widths of less than 1 millimetre, ideal sources for experimental purposes.

It is easy to show that the maximum producible energy is proportional to the square of the radius of the periphery of the apparatus and the square of the magnetic field. Experimentally it was proved that the value of the magnetic field which gave the most intense beam of ions agreed exactly with the calculated value. Since the time an ion spends inside an electrode is inversely proportional to the intensity of the magnetic field, it is clear that the resonance is very sharp, a change of 1 per cent. in the value of the field being sufficient to put the ions completely out of step with the electrical field after about fifty transits. Fortunately, it is not absolutely essential to have the magnetic field strictly uniform over a large region; small deviations may be permitted, and local adjustment of irregularities by means of thin iron sheets of requisite shape is easily possible.

So far, steps have not been taken to ensure particularly intense beams, and the collector currents have been of the order of 10^{-9} amperes. There seems to be no doubt that, even with the present source of ions, currents one hundred times as great can readily be obtained. A magnet with a pole face 114 cm. in diameter is now being installed in order to give a reasonably

uniform field of 14,000 gauss over a large region, and this should make possible the production of 25 million volt protons, if 50,000 volts at a wave-length of 14 metres can be supplied across the electrodes.

Splitting the Atom (L. F. B.)

In his opening address at the discussion on the structure of atomic nuclei, held at the Royal Society on April 28, Lord Rutherford referred to some extraordinary advances in our knowledge of nuclear physics which have resulted from the bombardment of light elements by protons. In the Recent Advances in Science Progress of last year reference was made to the work of Cockcroft on the production of protons with velocities corresponding to a fall through a difference of potential of 300 kilovolts.

Cockcroft and Walton have used these protons to bombard light elements, and have observed some new and striking phenomena. For example, when lithium is so bombarded with protons, whose potential drop is gradually increased, nothing remarkable happens until the drop exceeds 120 kilovolts. When the latter potential drop is exceeded, however, lithium gives off particles of range 8 cm. in air which produce scintillations on a zinc sulphide screen of brightness similar to those produced by α particles of the same range. If the potential drop is considerably increased there appears to be no increase in brightness of the scintillations, but their number increases rapidly.

Lord Rutherford stated that he felt sure that these scintillations were due to α-particles, although, as he pointed out, this must be verified by further experiment. He suggested, however, that even at the present stage it seemed possible to picture the phenomenon in the following way. A proton of mass 1 attaches itself to a lithium nucleus of mass 7 to form a lithium nucleus of mass 8. The latter may be supposed to be unstable, and to break up with the emission of two α-particles each of mass 4, and each corresponding to a potential drop of about 8 million volts, although produced by the impact of a proton with a drop not greatly exceeding 100,000 volts.

Similar disintegrations have been observed with other light elements. Thus boron gave bright scintillations corresponding to particles of range 4 cm. when the protons had traversed a potential drop of 135 kilovolts. Carbon gave particles of range 2·5 cm. of medium brightness for a potential drop of 250 kilovolts. Nothing definite was found with nitrogen, and nothing at all with oxygen. Copper, too, gave nothing. Aluminium gave particles of range 2·5 and fluorine of range

2·8 cm., when the potential drops exceeded 150 and 200 kilovolts respectively.

Superconductivity at High Frequency (S. K. L.)

The phenomenon of superconductivity, *i.e.* the sudden disappearance of electrical resistance as a metal is cooled to extremely low temperatures approaching absolute zero, is disturbed by various factors such as magnetic fields, tension in the conductor, and alloying with other metals. Previous attempts to examine the possible effect of employing high-frequency currents instead of direct currents yielded a negative result, but this has now been shown to be incorrect, errors having been introduced by the partial silvering in the vacuum flasks containing the liquid helium.

Some experiments on this effect are described by McLennan, Burton, Pitt, and Wilhelm in *Proc. Roy. Soc.*, A **829**, 1932, 52. Repeating their experiments with unsilvered flasks, they found that for currents at frequencies of the order of 10^7 cycles per second there is a depression of the critical temperature at which the sudden fall in resistance occurs. In the case of lead, at frequencies of 10^7 cycles per second, superconductivity was found to appear at less than 7° K., whereas with direct current the resistance vanished at 7·2° K. The experiments were performed with lead, tin, and tantalum, similar results being obtained in each case. A resonant circuit of a condenser and an inductance constructed entirely of the metal under examination was completely immersed in liquid helium. This resonant circuit was inductively coupled to a thermionic valve oscillator of orthodox design. By varying the frequency of this oscillator over a small range on each side of the resonant frequency, a change in the value of the anode feed current was observed from which could be deduced the high-frequency resistance of the resonant circuit. From a set of resonance curves taken at various temperatures of the liquid helium bath, the critical temperature at which the resistance falls could therefore be obtained. The curves showed a shift with a change of temperature due to the change in capacity by thermal contraction. In the later experiments with tin and tantalum, this shift was neutralised by an opposite shift of comparable amount when the liquid helium covered the condenser plates, its dielectric constant being 1·04.

The depression of the critical temperature became greater as the frequency was increased. Some difficulty was experienced in determining the critical temperature, since the disappearance of resistance with fall of temperature was less rapid with high-frequency current than with direct current. There was definite evidence, however, that the temperature at which

superconductivity appeared decreased as the frequency increased. By extrapolation, it appears that the limit would be reached at a frequency of 10^9 cycles per second corresponding to absolute zero.

Various experiments were performed in an attempt to discover the cause of the depression of critical temperature with increase of frequency. Systematic examination showed that it did not arise from the "skin effect" of the conductor resistance, nor from the heating of the coil by the high-frequency current, nor from the Silsbee effect (the depression of the critical point by the magnetic field produced by the current). The conclusion drawn is that it appears to be a function of the frequency of the current in the metal alone, and it is hoped that this discovery will provide a new line of attack on the fundamental problem of superconductivity.

The Grid-controlled Mercury-arc Rectifier. (S. K. L.)

The mercury-arc rectifier is a simple device consisting of an evacuated vessel of steel or glass containing a pool of mercury which functions as the cathode, and an insulated iron or graphite electrode as the anode. These rectifiers are built in large sizes weighing several tons, and capable of handling several thousand amperes. Smaller sizes often have oxide-coated cathodes in place of the large pool of mercury. The smallest rectifiers of this type are rated at a fraction of an ampere. Mercury-arc rectifiers have found many applications, superseding rotary converters and high-vacuum valves in several respects.

Their field of application is vastly extended by the introduction of a control electrode. This takes the form of a negatively charged grid, which provides an electrical screen between anode and cathode. Development of these controlled rectifiers has been very rapid during the past year. One of their most interesting and most important applications is to electric traction. An account of some recent demonstrations of the new rectifier by Brown Boveri & Company is given in the *Brown Boveri Review*, January 1932, and also in a paper by C. W. Olliver in *The Railway Engineer*, February 1932.

For traction purposes, of course, the rectifiers are of the large steel tank variety, rated at several thousand kilowatts. The control of these rectifiers is performed most economically, since the energy required to control the grid is only about 1/10,000th of the anode energy. The function of the grid is to control the starting of the discharge. A simple application of this principle is the regulation of D.C. voltage in rectifier plants. This is accomplished by suitably varying the grid

potential which determines the amount of current passing per half-cycle through each rectifier. Transformer tap switches and induction regulators are thereby eliminated.

Backfires in the rectifiers are extinguished, and short-circuits on D.C. networks are cleared with great simplicity by utilising the grid control. In normal operation, the negative potential of each grid (which is sufficient to withhold the discharge) is momentarily reduced by a rotating distributor at the instant at which the corresponding anode is required to conduct. In the case of an overload, a quick-acting relay breaks the lead from the commutator so that all the grids are maintained at a negative potential and no further discharge can occur. The action is so rapid that a high-speed main circuit breaker has nothing left to break by the time it has opened.

The grid-controlled rectifier provides an efficient and convenient frequency-changer. A particularly important case is the conversion of 3-phase 50-cycles into single-phase $16\frac{2}{3}$-cycles for railway locomotives. The process consists in rectifying the first six half-waves by applying a positive charge to the corresponding six grids, thereby giving a new half-wave of three times the length of the primary wave, and then rectifying in a similar way the next six half-waves from a second six-phase secondary winding. The resultant wave-form is not sinusoidal, but it can be given a correct shape easily.

The conversion of D.C. into A.C. by these rectifiers promises to be of great importance in industry, and may possibly revolutionise high-voltage transmission systems. The "inverter," as this arrangement is called, utilises practically the same circuit as the controlled rectifiers. Briefly, the operation consists in passing through the primary of the transformer the requisite current pulses released from the D.C. circuit by means of the controlled "rectifiers," the potentials of the grids being controlled either by a distributor or some other device such as a tuning fork. In these cases, the frequency is externally controlled, but automatic frequency control is made possible by coupling the grid circuit to the anode circuit. An apparatus for the conversion of D.C. to A.C. without rotating machinery is naturally in strong demand. The mercury-arc inverter is particularly attractive at high voltages, where the efficiency is of a very high order. It also has in its favour compactness and silence. There is also a demand for the small inverter. For instance, there has now appeared on the American market, an inverter suitable for operating A.C. mains wireless receivers from D.C. mains.

For the traction motor, the controlled rectifier solves many problems. One of the chief difficulties is the unsatisfactory commutation of single-phase motors of high frequencies, and

the controlled rectifier overcomes this by feeding the single-phase commutatorless motor with a frequency chosen at will, the power being obtained directly from the 50-cycle industrial supply. In principle, the operation is much the same as that of the commutatorless D.C. motor, in which a small synchronous motor drives the grid circuit distributor controlling the current pulses for the armature, so that, in effect, the controlled rectifier is the commutator. In the case of the commutatorless traction motor fed from the 50-cycle supply, the speed of the motor can be varied at will, independent of the voltage or frequency, merely by adjustment of the distributor. There is a further advantage in the regenerative braking provided by this system.

The ease with which all these operations may be performed is apparent when it is remembered that the energy in the controlling circuit is only a minute fraction of the controlled energy. This, and the high degree of efficiency and flexibility, are responsible for the present rapid development of the grid-controlled rectifier.

New Forms of Carbon. (M. S.)

It is somewhat unusual to find an element-catalyst undergoing rapid development in industry without the initial appearance of corresponding uses in pure science. Platinum, palladium, and nickel were of wide application in the laboratory, and industrial utilisation followed as a natural consequence. But apart from uses in vacuum work, charcoal in the form of activated animal and vegetable carbons does not play any appreciable rôle as catalyst or adsorbent in laboratory work comparable to the great progress made in large-scale processes. Such progress has furnished us with a number of porous materials with all gradations in physical properties; and a treatise on inorganic chemistry is sadly incomplete if it fails to include appreciable reference to these new forms and to the extent of their development. Furthermore, the pure chemist may yet find such materials of value as a catalyst in organic chemistry, particularly for halogenation, in a manner analogous to the use of them by the physical chemist in studies of adsorption phenomena.

The first point requiring attention in our texts is the necessity for classifying such artificial forms of the element into three groups according to their origin. There are the mineral carbons derived from soot, lignite, anthracite, etc.; the vegetable carbons formed by carbonisation of all types of organic waste materials, such as nut shells, rice hulls, peat, and wood waste; and the animal carbons, which include bone charcoal and blood carbon. All are prepared by carbonisation, accompanied or

followed by activation with a stream of inert gas or with the use of impregnating agent such as volatile salt or acid. It will be interesting to follow the possible attempts by the industry to produce a pure, amorphous carbon at an economical price in place of the sugar charcoal at present described as the purest amorphous form. A step in this direction is the large-scale production of a carbon of 97 per cent. purity by the carbonisation of the residues from the sodium-sulphite liquors of the cellulose industry.

Examples of the catalytic uses of these new materials are appearing from time to time, especially in chemical changes in which chlorine is the reactant. In the synthesis of phosgene from carbon monoxide and chlorine an activated bone charcoal is favoured ; but in the syntheses of sulphuryl chloride and of hydrogen chloride the use of the new carbons is becoming general. More recent instances are : the conversion of ethyl chloride to hexachlorethane, and the chlorination of saturated hydrocarbons to give various substitution products. An example of the use for bromination purposes is the preparation of hydrogen bromide by Boshovski and Danilitschenko [1] by passing water vapour over brominated charcoal at 500° C. The new carbons appear to be useful catalysts for effecting condensation in organic chemistry. Fischer, Bangert, and Pichler [2] have studied the conversion of acetylene into liquid hydrocarbons ; while a German syndicate has acquired patent rights for large-scale application of such reactions as the condensation of *m*-xylyl phenyl ketone to form *β*-methyl anthracene.

Agricultural History (G. E. Fussell)

The Agricultural History Society of America wishes to secure as full bibliographical information as possible relating to books or essays on agricultural history, currently published in the British Isles, for inclusion in successive issues of its quarterly journal. Writers of essays on farming history and the history of rural life in all its phases are therefore requested to forward details of their publications from time to time to the Associate Editor for Great Britain, Mr. G. E. Fussell, at 47 Maple Street, W.1. Information regarding sections of scientific works which contain historical data, works of general history or the history of specific trades or districts which contain sections dealing with agricultural history might also be included.

The quarterly journal of the Society, *Agricultural History,*

[1] *J. Russ. Phys. Chem. Soc.*, 1927, **59**, 851–9.
[2] *Brennstoff Chem.*, 1929, **10**, 279–82.

is obtainable on payment of an annual subscription of $3, which should be forwarded to the Treasurer, Agricultural History Society, Room 304, 1358 B Street, S.W., Washington, D.C., U.S.A.

Veterinary Research in Australia (Prof. T. Hare, M.D., M.R.C.V.S.)

In the recent opening of the F. D. McMaster Animal Health Laboratory a valuable addition has been made to the equipment of the veterinary research services of Australia. Mr. F. D. McMaster gave £20,000 to the Council for Scientific and Industrial Research for the erection of a laboratory in New South Wales to be devoted principally to research on problems relating to sheep. The building which houses the pathological, bacteriological, parasitological, and biochemical research units has been erected within the grounds of the University of Sydney alongside the University School of Veterinary Science. Dr. I. Clunies Ross, veterinary pathologist, has been appointed director, and work has already commenced on several diseases of sheep.

For some years the veterinary research laboratories at Glenfield in New South Wales and at the faculties of veterinary science of the Universities of Sydney and Melbourne have issued very valuable information, especially upon certain bacterial and parasitic diseases of sheep and on a large number of plants poisonous to live-stock. The breeders of sheep, which form one of the important industries of Australia, and the commercial firms concerned in sheep products have supported systematic research into the health and management of their stock with more enthusiasm and generosity than their fellows in Great Britain. The control of such serious diseases as foot-rot, pulpy kidney, infectious necrotic hepatitis, parasitic bronchopneumonia, and caseous lymphadenitis offers considerable difficulties in Australia owing to the conditions of rearing on extensive ranges susceptible to severe droughts. The generosity of Mr. F. D. McMaster is a striking testimony of the appreciation felt by the Australian sheep breeders for the achievements of their veterinary research services.

Much of this pioneer work has proved of great value to the control of disease in the sheep of Great Britain, and this country will derive additional benefits from the development at Sydney. Thus Great Britain and the Empire have reason to join with Australia in expressing gratitude for the F. D. McMaster Animal Health Laboratory and to wish it every success.

Rural Museums (W. Saunders)

In a Note which I contributed to SCIENCE PROGRESS on "The Museum Idea" (p. 687, No. 104, April 1932), I devoted

some attention to Scandinavian museum methods, and my attention has since been called to an article on "Rural Museums in Sweden," by Dr. E. Klein, of the Northern Museum, Stockholm, which appeared in *The Museums Journal* (30, No. 7, January 1931), the admirable organ of the Museums Association. Other articles, in numbers of the same periodical, which I have not yet seen, have dealt with "Open-air Folk Museums" and "Rural Museums," and the subject is thus clearly receiving the careful consideration of museum authorities throughout Britain. But absolute success in the formation and organisation of Folk, or Rural, Museums can only be attained when the inspiration and driving force is experienced by the Folk themselves. The movement throughout Scandinavia is unquestionably the outcome of a genuine Folk impulse, which, for some reason or another, has never been so self-assertive in Great Britain as it is to-day in Denmark, Norway, and Sweden. So far as I know Europe, there is less national flag-waving, for example, in any one country outside of Scandinavia, than there is in any individual town or district in the three small countries referred to. Whether it be the result of the natural and biological necessity of the small or insignificant animal to find other means than those of mere bulk in order to bring himself into the limelight, or merely a lack of self-consciousness, matters little. The fact remains that the Scandinavian peoples are determined to attain for themselves "a place in the sun," and, in the process, they in particular, and the world in general, are acquiring a cultural asset and creating for posterity an historical legacy, the actual material and sentimental values of which can never be estimated in any sort of currency that human ingenuity has ever conceived.

That the British races are, on the other hand, afflicted by the disease—or whatever psycho-analysts may choose to call it—of self-consciousness, is a fact that has invariably been too self-evident to admit of one moment's dispute. Even when they sing "Rule Britannia" at political meetings or heroic receptions, in the privacy of their town or village halls, they do so with a certain shame-facedness that, were it universally known, would undoubtedly become the wonder of the world. And every student and collector of folklore in this country is aware of the well-nigh insuperable difficulties that are encountered at nearly every turn. The folk-song or story that one would almost sell one's soul to obtain is not forthcoming, too frequently because "our honours" were sure to find it too trifling a thing for our superlative minds to trouble about. These old people, who are now generally the sole remaining repositories of the lore we are so anxious to obtain, judge us, alas, in too many instances, by the attitudes adopted by their

own miserable and "ultra-modern" descendants. The so-called march of progress also, is the arch-enemy of the working folklorist and of the would-be founder of the Folk, or Rural, Museum. Even in Scandinavia, the worker in that field has, in many aspects of the subject, arrived too late. And every year in rural and in urban Britain, the Royal Commission on Ancient and Historical Monuments notwithstanding, invaluable and absolutely irreplaceable landmarks in the cultural development of the Folk are being ruthlessly torn to pieces and ground into oblivion.

If, then, we are to stay this insane iconoclasm and vandalism, immediate action is imperative. But how can this possibly be achieved? The historical mind which, in Britain, never has been widely disseminated, is certainly not becoming any more common, and we are constantly hearing of such collections as have been in existence for generations, amongst rural communities, being dispersed, and museums being closed down for lack of interest and funds, so that the outlook for the future is by no means too rosy. There is, however, one ray of hope which has recently shone in upon my own consciousness. In the interpretation of Folk-song and Dance, the Women's Rural Institutes throughout the land have made creditable appearances, and they have already given unmistakable evidences of their close and sympathetic association with the people concerned. Why, then, not enlist the services of these Institutes, at any rate where other bodies are non-existent or not available? Someone in authority should, of course, pay a preliminary visit, and explain the general aim and purpose of the idea, and, if possible, plan out a mode of procedure. And in every case, likewise, the parish priest or minister, the schoolmaster, and the doctor, to say nothing of the county gentry, should be approached even before the matter is placed before the Institute. Land in most country districts is cheap enough, and sufficient for such a purpose as that of accommodating a Folk Museum should, in most of the localities, be obtained at a nominal rental, or even for the asking; and frequently a subject, such as a ruined castle or tower, an abandoned church, some quaint old inn, farm-house, or barn, may be found *in situ*, and obtained as a nucleus for the proposed complete museum.

These institutions do not, of course, spring up in a night, and can never be regarded as having reached a state of completion. The museum, like the library, the school, and the university, is a living organism, ever growing, yet never immune from death and decay. It must be carefully nurtured and fed; it must be tended also as a tree that grows; injurious or useless excrescences must be removed without compunction, and no opportunity of filling in gaps neglected,

when such is necessary. But the first objective must lie in the fostering and creation of a new museum spirit in the hearts and souls of those who are to undertake the material initiation of the scheme, and of working up a sufficient degree of local patriotism, enthusiasm, and esprit de corps amongst the general mass of the people themselves. That the achievement of this is no vain illusion has recently been proved in the small rural hamlet of Dalmeny, in Midlothian, where the parishioners, without any extraneous aid whatever, have almost completely restored their parish church, " the most perfect Norman parish church, which still remained . . . as a witness to the idealism, the genius, and the craftsmanship of that wonderful period of ecclesiastical architecture, the twelfth century." Here, then, for what it is worth, is an idea which the Museums Association might take into consideration.

Notes and News

The names of those elected to the Fellowship of the Royal Society this year are as follows : Prof. F. C. Bartlett, professor of experimental psychology, Cambridge ; Prof. Davidson Black, anatomist, Peking ; Dr. F. W. Carter, of the British Thomson-Houston Co., Rugby ; Prof. W. G. Fearnsides, Sorby professor of geology in the University of Sheffield ; Prof. F. E. Fritsch, professor of botany, East London College ; Prof. J. A. Gray, research professor of physics, Queen's University, Ontario ; Prof. J. B. S. Haldane, biochemist, Cambridge ; Prof. D. R. Hartree, Beyer professor of applied mathematics, Manchester ; Dr. K. Jordan, zoologist, Tring ; Prof. F. R. Miller, professor of physiology, Western Ontario ; Sir Basil Mott, past-president of the Institution of Civil Engineers ; Dr. J. B. Orr, Rowett Research Institute, Aberdeen ; Prof. J. L. Simonsen, professor of chemistry, University College, Bangor ; Mr. T. Smith, National Physical Laboratory ; Prof. H. S. Taylor, professor of physical chemistry, Princeton University ; Prof. H. W. Turnbull, professor of mathematics, St. Andrews ; Prof. Warrington Yorke, professor of tropical medicine, Liverpool.

The long winter took a heavy toll of the veterans of science, and our obituary list this quarter is much longer than usual. It includes Sir Frederick Andrewes, F.R.S., pathologist of the University of London ; Dr. L. A. Bauer, the eminent magnetician ; M. Gillaume Bigourdan, at one time president of the Paris Academy of Sciences ; Dr. R. M. Brontë, pathologist ; Prof. W. R. Dron, professor of mining in the University of Glasgow ; Dr. G. C. Druce, botanist and pharmacist of Oxford ; Sir David Drummond, emeritus professor of medicine, Durham ;

Sir Arthur Duckham, fuel technologist; Dr. W. D. Dye, F.R.S., of the National Physical Laboratory; General G. Ferrié, formerly president of the Committee on Longitudes of the International Astronomical Union; Sir Patrick Geddes, biologist; Principal E. H. Griffiths, of the University College of South Wales; Dr. Alfred Hay, sometime professor of electrotechnology at Cooper's Hill and at Bangalore; Dr. Victoria Hazlitt, lecturer in psychology, Bedford College, London; Mr. J. J. Joicey, collector and lepidopterist; Mr. H. Chapman Jones, chemist; Prof. P. N. Kryloff, of Tomsk, botanist; Prof. D. H. Marshall, emeritus professor of mathematics and physics, Queen's University, Ontario; Dr. James Mercer, F.R.S., lecturer in mathematics, Christ's College, Cambridge; Wilhelm Ostwald, N.L.; Dr. Michael Perkins, zoologist; Prof. H. J. Priestley, professor of mathematics in the University of Queensland, Brisbane; Mr. Eustace Short, of aeroplane construction fame; Sir William Smith, at one time professor of forensic medicine at King's College, London; Sir William Somerville, emeritus professor of agriculture in the University of Oxford; Mr. Richard South, editor of the *Entomologist*; Prof. E. Wilson, lately professor of electrical engineering, King's College, London; Prof. R. Stenhouse Williams, first director of the National Institute for Research in Dairying.

H.M. the King has approved the award of the Founder's medal of the Royal Geographical Society to Mr. H. G. Watkins, for his work as leader of the British Arctic Air Route Expedition, and of the Patron's medal to H.R.H. the Duke of Spoleto, who led the Karakoram Expedition in 1929.

Sir Oliver Lodge has been awarded the Faraday medal by the Institution of Electrical Engineers; Sir William Pope the Messel medal by the Society of Chemical Industry, and Mr. C. T. R. Wilson the Duddell medal by the Physical Society.

Dr. Theobald Smith has been awarded the Manson medal by the Royal Society of Tropical Medicine. This medal is awarded triennially, and the last award, in 1929, was made to Sir Ronald Ross.

Sir James Jeans has been elected an honorary member of the Washington Academy of Sciences.

The Council of the Institution of Civil Engineers has awarded Telford gold medals to Prof. C. F. Jenkin, of Oxford, and to Sir Bernard Darley, of Bahawalpur. A Stephenson gold medal has been awarded to Mr. B. G. White (London).

Gold medals have been awarded to Sir Harold Carpenter and Dr. T. A. Rickard by the Council of the Institution of Mining and Metallurgy.

The Neill prize for the years 1929–31 has been awarded to Dr. C. H. O'Donoghue by the Royal Society of Edinburgh.

The following is a list of the presidents of some of the scientific societies.

Royal Astronomical Society: Dr. H. Knox Shaw; *Physical Society:* Prof. A. O. Rankine; *Geological Society:* Sir Thomas Holland; *Ray Society:* Sir Sidney Harmer; *Quekett Microscopical Club:* Mr. J. Milton Offord; *Association of Economic Biologists:* Dr. W. B. Brierley.

Mr. W. S. Morrison, M.P., has been appointed to succeed Major A. G. Church on the Medical Research Council.

The fourteenth International Physiological Congress will be held at Rome on August 28 to September 3. The president-elect is Prof. Bottazi of Naples. Prof. A. V. Hill will deliver the inaugural lecture.

The sixth International Botanical Congress will be held at Amsterdam on September 9 to 14, 1935. Prof. F. A. F. C. Went, of Utrecht, has been elected president, and Dr. M. J. Sirks, of the Landbouwhoogeschool, Wageningen, secretary.

The members of the Optical Society and of the Physical Society of London have agreed to the amalgamation of the two Societies. The amalgamation will take place so soon as the necessary alterations in the articles of association of the Physical Society have been made. We understand that it has been brought about by the difficulty experienced by the Optical Society in obtaining suitable papers and a reasonable attendance at its meetings.

The Second Report of the Committee on Atomic Weights of the International Union of Chemistry (Paris, 49 Rue des Mathurins) contains the recommendation that the atomic weights of krypton and xenon should be taken as 83·7 and 131·3 respectively, instead of 82·9 and 130·2 as at present. It is agreed that atomic weights shall continue to be based on the figure 16 for the chemical unit O, and not on the isotope of oxygen O^{16}, which would make the chemical O equal to $16 \times 1{\cdot}00022$, owing to the presence of the isotopes O^{17} and O^{18} in the chemical unit.

Bulletin 86 of the National Research Council, Washington, D.C. (price $1·50), forms the Second Supplement to the *Bibliography of Bibliographies on Chemistry and Chemical Technology.* It covers the period 1929–31, and contains approximately 3,300 bibliographies under 950 headings. As the title indicates, the book is a compilation of bibliographies published as separates, or at the end of books or magazine articles, or as footnotes to the same, on the numerous aspects of pure and applied chemistry. Each entry gives the name of author or compiler, title, and place of publication. The

majority of the entries state the number of references, thus giving an indication of the completeness of the particular bibliography, and they are all classified under subject-headings alphabetically arranged.

The Cambridge University Press announces that two new volumes in the series "Cambridge Tracts in Mathematics and Mathematical Physics" will be published shortly. They are *Modular Invariants*, by Mr. D. E. Rutherford, and *Conformal Representation*, by Prof. C. Caratheodory. Allen & Unwin are publishing a new book by Max Planck in the autumn. The title is *Where is Science Going?*, and it will have an introduction and epilogue by Einstein. Bell's, also, in the autumn hope to have ready Sir William Bragg's new book, *The Universe of Light*. The Oxford University Press are publishing the *Correspondence and Papers of Edmond Halley*, arranged and edited by E. F. MacPike. Owing to the kindness of Mr. H. W. Robinson, the assistant librarian of the Royal Society, we have seen the MS. of this book, and can vouch for its extraordinary interest to those concerned with the history of the Newtonian period. The same publishers are also issuing a new book by E. B. Moullin, entitled, *Principles of Electro-Magnetism*, and intended more especially for the engineer.

Messrs. Adam Hilger Ltd. have obtained a prolongation of the patents covering the Twyman-Green Interferometer for a further ten years from January 3, 1932. This instrument is designed for tests on prisms and lenses, and makes it possible to construct optical systems of a degree of perfection which would be quite unobtainable without it. In a brochure on the instrument, Messrs. Hilger state that two of their licensees—Messrs. Ross Ltd. and Messrs. Taylor, Taylor & Hobson—have been able to export to the United States large numbers of optical elements as a result of the installation of these interferometers. Most of the large cinema projectors in the United States are fitted with Ross lenses, and the great proportion of the cinema camera lenses are supplied by Messrs. Taylor, Taylor & Hobson. The German rights have been purchased by Messrs. Carl Zeiss, Jena.

In the *Bell Laboratories Record* and in the *Physical Review* for January, P. P. Cioffi describes the properties of hydrogenised iron. The chief features of the magnetic behaviour of this iron are its very high initial and maximum permeabilities and its very low coercive force. Indeed, hydrogenised iron appears to have better characteristics than single crystals of iron, which can now be grown to a large size in hydrogen or *in vacuo*. The best magnetic specimens of hydrogenised iron have been obtained in the form of rings of Armco iron, which were first heated in moist hydrogen at 1475° C.—*i.e.* just below

the melting-point—for 18 hours, cooled to 880° C. in 1 hour, and, finally, annealed at that temperature for 12 hours before being allowed to cool slowly to room temperature. For such specimens the initial permeability was 4,000, and the maximum permeability 180,000. The coercive force was only 0·025 gauss, and the hysteresis loss for a maximum induction of 14,000 lines per sq. cm. was only 190 ergs per c.c. per cycle. The presence of moisture during treatment appears to be essential, and there seems to be little doubt that some catalytic action results in a purification of the iron. The time the iron is kept at the highest temperature depends on the dimensions of the specimen, thicker specimens requiring longer treatments.

The *Annual Report of the Indian Association for the Cultivation of Science* for the year 1930 is published by the honorary secretary, Sir C. V. Raman, in vol. VI, Part 6 of the *Indian Journal of Physics*. Twenty-eight research students were working in the laboratory during the year, and 51 papers were published: 38 in the *Journal*, 7 in *Nature*, and the remainder in the *Proceedings* of various scientific societies. The financial statement shows a very large and unexplained increase in the "Floating Balance in the Bank," and the general position appears to be very satisfactory. The accounts include detailed statements of the costs of the various services, and a detailed valuation of the whole of the assets. One can only regret that it is not obligatory for the various departments of English Universities and Technical Colleges to prepare similar statements. The same number of the *Journal* contains an interesting paper by Malurkar and Ramdas on the variation of temperature in the air very near the ground and its effect in producing mirage, and an account of experiments on magnetic double refraction in aqueous solutions of paramagnetic salts by S. W. Chinchalkar. This new phenomenon occurs notably in solutions of salts of the rare earths, and the birefringence is sensibly proportional to the square of the field strength.

The Bell System *Technical Journal* for January 1932 (vol. XI, No. 1) contains a number of papers of very great interest to the physicist. J. B. Johnson contributes an article, reprinted from the *Journal of the Franklin Institute* (December 1931), on the Cathode-ray Oscillograph, which describes the development of the instrument since its discovery by F. Braun in 1897, and its application to various problems in science and technology. The paper should be consulted by all those interested in oscillographs. F. B. Llewellyn has a long and important paper on the design of oscillators giving a frequency independent of normal variations in the operating voltages (though not of the effects of temperature variations due to changes in operating currents), and in his twenty-third paper,

on "Contemporary Advances in Physics," Karl K. Darrow gives a very complete account of cosmic rays. The annual subscription to the *Journal* is $1·50, but single copies can be obtained from the American Telephone & Telegraph Co., 195 Broadway, New York, price 50 cents + 9 cents for foreign postage.

The Bureau of Standards *Journal of Research* for January and March 1932 contain two papers by Lauriston S. Taylor, on X-ray standards. The unit is the *Röntgen*, defined as the quantity of X-radiation which, when the secondary electrons are fully utilised and the wall effect of the (ionisation) chamber is avoided, produces in 1 c.c. of atmospheric air at 0° C. and 76 cm. pressure such a degree of conductivity that one electrostatic unit of charge is measured at saturation current. X-ray dosage is measured in terms of this unit by dosage meters calibrated against standard open-air ionisation chambers set up at the Bureau of Standards, the National Physical Laboratory, the Physikalisch-Technische Reichsanstalt and l'Hôpital St. Antoine, Paris. The units employed at these several laboratories have been compared by means of a portable equipment taken from one to the other by Mr. Taylor, and the results show an agreement to within ± 0·5 per cent. for the United States, England, and Germany. The unit used by Dr. Solomon in Paris is 2·29 röntgens. The January issue of the *Journal* contains an account of these experiments, and, in March, the author discusses the application of air density corrections to different types of ionisation chambers.

The Bakelite Co., of 68 Victoria Street, S.W.1, issue a monthly journal entitled *Bakelite Progress* to make known the manifold uses of their product. Copies of the journal are sent on request, and since it contains many useful hints, it is worth asking for.

ESSAY-REVIEW

GROUP THEORY AND QUANTUM THEORY. By Prof. G. TEMPLE Ph.D., D.Sc. Being a review of **The Theory of Groups and Quantum Mechanics**, by HERMANN WEYL, translated from the 2nd (revised) German edition by H. P. ROBERTSON. [Pp. xxii + 422.] (London: Methuen & Co., 1931. Price 21*s*.)

THE two most important books hitherto published on the subject of the quantum theory are *The Principles of Quantum Mechanics*, by Dirac, and *Gruppentheorie und Quantenmechanik*, by Weyl, the English translation of which is reviewed in this article. In Dirac's work the quantum theory is studied for its own sake as the basis of microscopic physics, while in Weyl's work the quantum theory is introduced as a field for the application of the theory of finite and continuous groups. This presentation of the quantum theory from a standpoint which is almost exclusively mathematical has a twofold advantage: it clarifies, condenses, and develops the mathematical language in which the theory is expressed, and therefore prepares the way for more profound and systematic statements of the physical principles of the theory.

The plan of this book is dominated by the theory of groups. It may be rapidly summarised as follows: Chapters I and II are introductory in character. The first chapter gives a general account of linear algebras and unitary geometry, and the second translates into this abstract terminology the physical concepts of wave mechanics. The stage is thus set for the entrance of group theory. Chapter III develops the elementary theory of the representations of groups, and Chapter IV systematically applies these results to the quantum theory. In Chapter V the representation theory is formally expounded in terms of group algebra, and is applied to more complex problems of atomic physics.

The mode of presentation of the subject is entirely characteristic of the author, and it abundantly illustrates his astonishing powers of condensation, of abstraction, and of seeing relations between remote branches of mathematics. Naturally these features make the book difficult reading for a novice, but they contribute enormously to the enjoyment of the student who is already familiar with group theory and quantum theory.

A typical example of these characteristics of Weyl's writing is furnished by his definition of a group in terms of the concept of "equivalence" (p. 112). An element p' is said to be equivalent to an element p with respect to a set of transformations G if there exists a transformation of the set which transforms p into p'. The conditions that the set G should form a group can then be expressed in nine words—the relation of equivalence is reflexive, symmetrical, and transitive. The diamond-like precision and lucidity of this definition must give to the mathematician an intellectual joy comparable to that afforded by a Bach fugue.

In fact, the whole book is replete with delights for the pure mathematician, who will see with mingled surprise and pleasure that the most abstract results in group theory have an immediate application to quantum mechanics. The physicist, however, will put down this book with the inevitable query, "Are the methods of group theory really necessary and unavoidable in solving the problems of the quantum theory?" Nor will he be satisfied with the reply given by Dirac,[1] that "group theory is just a theory of certain quantities that do not satisfy the commutative law of multiplication, and should thus form a part of quantum mechanics, which is the general theory of all quantities that do not satisfy the commutative law of multiplication." After all, the quantum theory is primarily a branch of physics (unless, indeed, it is the root of all physics!), and mathematical terminology is simply the language in terms of which it is expressed. It is therefore essential to discuss *ab initio* the fundamental question raised by this book, "In the development of quantum mechanics are the methods of group theory a necessity or a luxury?"

To answer this question it is necessary to refer to the principles of the quantum theory, and to realise that these principles fall into two sets, which may be conveniently distinguished as the "general" and the "special" principles. The general principles assert that the proper expression of physical quantities is by means of the elements of some non-commutative algebra; the special principles determine the particular algebra which is most appropriate. The general principles can be based on a critical study of the nature and conditions of physical measurement; the special principles, such as Heisenberg's exchange relations, have no such philosophical justification, but are simply bold hypotheses.

The special principles are indispensable for a complete formulation of the quantum theory, and, once they have been postulated, the theory can be developed quite independently of any explicit reference to the theory of groups. The work of

[1] *Proc. Roy. Soc.*, A. 123, 716, 1929.

Dirac furnishes an excellent example of this autonomous development. At the same time there are a number of important problems which can be discussed without the use of the special principles, *e.g.* the theory of the angular momentum operators and the theory of the structure of atoms with many electrons. For the theorist engaged in a critical study of the foundations of the quantum theory it is clearly important to draw a sharp distinction between the two classes of problems whose solutions are or are not independent of the special principles. For the first class of problem the methods of group theory are indispensable, for the second class of problem they are ineffective or superfluous.

Weyl's work is not exclusively occupied with this class of problem, but in the treatment of the second class of problem it confirms the statement made above. The most important example of this class is the problem of the actual form of the Hamiltonian operator. In non-relativistic theory this operator is constructed by direct analogy with classical models; in relativistic theory Dirac's linear wave equation is derived from a principle of least action. Here group theory is of no avail, and recourse is had to more or less plausible auxiliary assumptions.

To return to the principles of quantum theory and their relation to the theory of groups, it appears that the fundamental concepts of the quantum theory are the concepts of a physical system, of the states of a system, and of the transitions from one state to another. The *general* principles of the quantum theory are that a definite state of a system is represented by a ray, or unit vector, in the Hilbertian space of the system, and that a transition is represented by a unitary transformation in this system space. A physical quantity associated with the system is represented by a Hermitian operator, *i.e.* by the operator of an infinitesimal unitary transformation. The mean value of a physical quantity averaged over a certain statistical aggregate of systems is then uniquely determined by a remarkable theorem due to J. v. Neumann.

Now a transformation of the kinematical co-ordinates describing a system "induces" a corresponding transformation in the system space, and a group of congruence transformations in geometrical space induces an isomorphic group in the system space. Hence certain groups of transformations in system space are completely determined as to their structure and "multiplication table" without any appeal to the special principles of the quantum theory. The matrix representations of these groups of transformations can then be determined directly.

The standard method for the complete determination of the

irreducible representations of a given abstract group is expounded in the last chapter by means of the theory of group algebra, and may be briefly summarised as follows: Let **s**, **t**, . . . denote the operators of a group. Let the operator **x**, defined by the equation,

$$\mathbf{x} = \sum_{\mathbf{s}} x(\mathbf{s}).\, \mathbf{s},$$

be represented by the vector with components $x(\mathbf{s})$ in space $\mathfrak{H}$ with dimensions equal in number to the order of the group. Then, if

$$\mathbf{x}' = \mathbf{a}\, \mathbf{x},$$

it follows that

$$x'(\mathbf{s}) = \sum_{\mathbf{t}} a(\mathbf{s}\mathbf{t}^{-1})\, x(\mathbf{t}).$$

By means of this equation the operator **a** is associated with a certain linear transformation in the vector space $\mathfrak{H}$. Hence the given abstract group is represented by a linear homogeneous group in $\mathfrak{H}$. From this "regular" representation it is possible to deduce all the irreducible representations of the group and to establish the classical theorems on group characteristics.

In the case of the rotation group it is possible to construct the irreducible representation by more elementary methods, and to verify their irreducibility and completeness by a subsequent investigation. The infinitesimal operators of the rotation group in geometrical space are

$$\begin{array}{ll} R_x & \dot{x} = 0,\ \dot{y} = -z,\ \dot{z} = y\,; \\ R_y & \dot{x} = z,\ \dot{y} = 0,\ \dot{z} = -x\,; \\ R_z & \dot{x} = -y,\ \dot{y} = x,\ \dot{z} = 0\,; \end{array}$$

and the corresponding operators in the system space, or rather those operators multiplied by $ih/2\pi$ represent the components of angular momentum, M_x, M_y, M_z.

The representations of the corresponding group induced in the system space are determined by the dimensions of the matrices. In three dimensions there is clearly the representation:

$$\begin{Vmatrix} 0 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{Vmatrix}, \quad \begin{Vmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{Vmatrix}, \quad \begin{Vmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{Vmatrix}.$$

From this representation it is possible to construct representations in two dimensions and in n dimensions.

Since $x^2 + y^2 + z^2$ is an invariant of the rotation group, the rotations in the invariant sub-space

$$x^2 + y^2 + z^2 = 0$$

also form a group. In terms of new variables, ξ, η, defined by the equations

$$x = -\xi^2 + \eta^2,\ \iota y = \xi^2 + \eta^2,\ z = 2\xi\eta,$$

the operators of this group are:

$$\begin{array}{ll} R_x & \dot{\xi} = -\tfrac{1}{2}\iota\eta,\ \dot{\eta} = -\tfrac{1}{2}\iota\xi; \\ R_y & \dot{\xi} = -\tfrac{1}{2}\eta,\ \dot{\eta} = \tfrac{1}{2}\xi; \\ R_z & \dot{\xi} = -\tfrac{1}{2}\iota\xi,\ \dot{\eta} = \tfrac{1}{2}\iota\eta; \end{array}$$

whence we have at once a two-dimensional representation of the angular momentum operators with matrices,

$$\frac{h}{4\pi}\begin{Vmatrix} 0 & 1 \\ 1 & 0 \end{Vmatrix},\quad \frac{h}{4\pi}\begin{Vmatrix} 0 & -\iota \\ \iota & 0 \end{Vmatrix},\quad \frac{h}{4\pi}\begin{Vmatrix} 1 & 0 \\ 0 & -1 \end{Vmatrix}.$$

i.e. Pauli's spin matrices.

A representation in $(2j + 1)$ dimensions can now be constructed from the invariant

$$I = \xi^*\xi + \eta^*\eta,$$

where ξ^*, η^* are the complex conjugates of ξ, η. Let

$$x_m = \frac{\xi^r\,\eta^s}{(r!\,s!)^{\frac{1}{2}}},$$

where $\qquad m = \tfrac{1}{2}(r - s)$ and $j = \tfrac{1}{2}(r + s)$.

Then $\qquad I^{2j} = (2j)!\sum_m (x_m^* x_m).$

Since I is an invariant, the operators R induce a linear transformation in the variables x_m, and the actual form of the transformation for the operators $R_x + iR_y$, $R_x - iR_y$, R_z is easily found to be

$$\begin{aligned} \dot{x}_m &= -\iota x_{m-1}\ (j + m)^{\frac{1}{2}}\ (j - m + 1)^{\frac{1}{2}}, \\ \dot{x}_m &= -\iota x_{m+1}\ (j - m)^{\frac{1}{2}}\ (j + m + 1)^{\frac{1}{2}}, \\ \dot{x}_m &= -\iota m x_m. \end{aligned}$$

Hence the only non-zero elements in the representation of $M_x \pm \iota M_y$, M_z as $(2j + 1)$ dimensional matrices are:

$$\begin{aligned} (M_x + \iota M_y)\,(m, m - 1) &= (j + m)^{\frac{1}{2}}\,(j - m + 1)^{\frac{1}{2}} h/2\pi, \\ (M_x - \iota M_y)\,(m, m + 1) &= (j - m)^{\frac{1}{2}}\,(j + m + 1)^{\frac{1}{2}} h/2\pi, \\ M_z\,(m, m) &= mh/2\pi. \end{aligned}$$

This is perhaps the most striking example of the use of the theory of representations in quantum mechanics. The abstract results of group theory now acquire a new vitality. The

Clebsch-Gordan theorem for the rotation group can be used to justify the empirical rule of spectroscopy for the composition of the angular momenta of kinematically independent systems, and then applied to the theory of the spinning electron and of multiplet structure. Finally, it may be used, in conjunction with Schur's lemma, to deduce the standard selection and intensity rules!

After the rotation group the most important congruence group is the group of permutations of similar particles. The results obtained from the theory of the representations of this group lay the foundation of the whole theory of atomic and molecular structure. These results are of fundamental importance for the physicist and chemist.

Enough has been said to indicate the wide range and fundamental importance of the results obtained by group theory in quantum mechanics. The world of mathematical physicists is under a great debt to Prof. Weyl for having expounded this subject with such charm and clarity. The theory of groups has long been the Cinderella of mathematics. Let us hope that the transformation scene is at hand.

REVIEWS

MATHEMATICS

Numerical Mathematical Analysis. By J. B. SCARBOROUGH, Ph.D. [Pp. xiv + 416.] (Baltimore: Johns Hopkins Press; London: Humphrey Milford, 1930. Price 25*s*.)

IT is clear from Dr. Scarborough's book that he is a computer of skill and experience to whom formulæ are tools to be used with discrimination and knowledge. In numerical analysis the sign of equality has only a phantom existence, and without some discussion of the errors they involve the formulæ are of little value. The reader of this book is never allowed to lose sight of this cardinal fact. The first chapter is headed "The Accuracy of Approximate Calculations," and three other chapters, as well as a number of shorter sections, are devoted to discussions of the accuracy of the formulæ developed.

Much of the book is, necessarily, on standard lines. The usual interpolation formulæ are developed, and lead on to formulæ for numerical integration, the accuracy of all these being carefully discussed. Welcome features are the sections on interpolation with two independent variables and on the evaluation of double integrals. The solution of algebraic equations is next considered, the root squaring method being given special prominence.

The chapters on the numerical solution of differential equations are among the best in the book. The method of successive approximation is very fully treated, while the methods of Adams, of Runge, and of Milne are all dealt with.

The Normal Law of Error, the Method of Least Squares, and their applications to the combination of observations and to curve fitting are all treated in a practical and convincing manner. The author has thought it worth while to attempt a proof of the Normal Law. His proof is ingenious and more easy of understanding by a beginner than many others, while, since he does not claim rigour for it, it is difficult to level criticism at it on logical grounds. But it may be doubted whether any proof should be given in a work of this kind. The Normal Law has no inevitability, and, in practice, it is almost impossible to predict in what cases it will appear. To establish it theoretically at the very threshold of a discussion of frequency distributions is to exaggerate its importance, and may fix in the mind of the student ideas which will have to be eradicated at a later stage.

A chapter on numerical Fourier Analysis completes the work. Correlation and the periodigram are among the subjects for which no place has been found. Examples are given at the ends of all the chapters, and add to the usefulness of the book. Dr. Scarborough is to be congratulated on the production of a thoroughly sound and practical work, and one which certainly has few equals in its field.

R. C. J. H.

Vector Analysis. By RICHARD GANS. [Pp. ix + 163.] (London: Blackie & Son, 1932. Price 12*s*. 6*d*.)

PROF. GANS's little textbook has had considerable success in Germany and, at a time when good English works on vector analysis are rare, a translation was

well worth while. Miss Deans, who has already put us in her debt by her edition of De Broglie's papers, has once more done her work well, and has produced a very readable book.

The needs of the physicist are kept in mind throughout, and at least a third of the space is given to applications. In what remains the elements of the theory are developed in a clear and usually satisfactory manner. Line and surface integrals are discussed, and the usual vector operations in curvilinear co-ordinates are introduced.

A chapter on tensors follows. Here the author starts from the point of view of the linear vector function, so that a tensor appears from the start as an operator having three principal axes and associated with a fundamental ellipsoid. Such tensors are of a restricted type, but are sufficient for the applications to electricity and hydrodynamics that occupy the last, and perhaps the most valuable, chapter.

The author's slight casualness with regard to such matters as the continuity and differentiability of his functions may readily be forgiven in a book written for the physicist rather than the mathematician. Apart from this there are a few minor blemishes. The graphical representation of a vector field as a collection of tubes that is given in Chapter I is impossible for vectors in general. Manifestly it requires that there should be some relationship between the vectors at neighbouring points of the field, a relationship which appears to be expressed by the vanishing of the divergence. Again, the author does not distinguish between free and located vectors, although he makes use sometimes of the one type and sometimes of the other. But these are not things likely to lead the student far astray, and they are counterbalanced by much that is excellent.

Many examples are given, and answers, with some brief solutions, are provided at the end of the book. There is also a summary of the principal formulæ. The publishers have maintained their high standard of mathematical printing, and have issued the book in the pleasant and serviceable format which has now become familiar, and does not cease to be welcome.

R. C. J. H.

Die elliptischen Funktionen von Jacobi. By L. M. Milne-Thomson. [Pp. xiv + 69.] (Berlin: Springer, 1931. Price 10.50 marks.)

The modern mathematical physicist will undoubtedly welcome the tabulation of Jacobi's elliptic functions. The tables before us give 5-figure values, with differences, of sn u, cn u, and dn u, at intervals of 0·01 in u, and for values of k^2 (the square of the modulus) at intervals of 0·1 from 0·0 to 1·0. The use of k^2 as an argument, instead of the angle α where $\sin \alpha = k$, has been adopted by earlier tabulators in this field, for example by Nagaoka and Sakurai, so that no originality can be claimed. The tabulation for each value of k^2 extends to a convenient point beyond the corresponding quarter-period K. A supplementary table gives 8-figure values of the complete elliptic integrals K, K', E, E' and the number q at intervals of 0·01 in k^2. Five pages of formulæ and three graphs of the functions tabulated complete the volume.

The omission of decimal points is not good tabular practice. Signs have been omitted to such an extent that the user, unless he is very wary, will be trapped; for instance on p. 40, in the column cn u for $k^2 = 0{\cdot}6$, the absence of signs would lead to the inference that the function was positive, whereas the contrary is the case. The tables have been unduly spread out by the use of large type and small pages; the cost per figure is ten times as great as in the four-figure tables with which the author was associated. Further, it seems unpatriotic for an Englishman to seek a foreign publisher.

L. J. C.

The Law of Gravitation in Relativity. By H. C. Levinson, Ph.D., and E. B. Zeisler, Ph.D. [Pp. 126.] (Chicago: University of Chicago Press, Second Edition, 1931. Price 16s.)

The authors of this volume have essayed a difficult task and appear to have carried it to a successful conclusion. Starting from broad assumptions, they have aimed at discovering all possible laws of gravitation consistent with the Principle of Relativity. Their assumptions are: (1) that the geometry of space is Riemannian, and has a quadratic differential line element; (2) that the law of gravitation is covariant; (3) that the law is expressible as a set of differential equations in the $g_{\mu\nu}$ alone, not involving differential coefficients above the second order, and linear in the second-order terms. To these they find it necessary to add a further assumption, that every set of covariant equations is equivalent to a set of tensor equations, a statement that should be capable of proof, but which they have been unable to establish.

They develop the theory of tensors more logically and with greater thoroughness than is the custom in books on Relativity and, in consequence, are able to prove that only a definite number of tensor equations satisfy these conditions and to find all these explicitly. They find that there are eight possible laws of gravitation, of which Einstein's is one. The eight are formed from linear combinations of four tensors, one of which they claim as a new discovery.

Of the seven laws other than Einstein's, some are shown to be inadequate, but some interesting new possibilities appear. For example, in one system the planets have fixed perihelia, while light is not deflected by the sun, so that an almost entirely Newtonian mechanics is consistent with the fundamental postulates.

The apparent arbitrariness of Einstein's law and its sudden incredible appearance from under its author's hat have always been a trouble to many mathematicians who, although they learned to do the trick for themselves quite efficiently, have continued to feel that there might be an element of fraud in it somewhere. Books like the present will help them to feel more at home in a still rather trackless land, and perhaps to find new paths for themselves through the tangled undergrowth of ideas that darken it.

R. C. J. H.

Mathematics. A Textbook for Technical Students. By B. B. Low, M.A., A.M.I.Mech.E., A.M.I.A.E. [Pp. vi + 448.] (London: Longmans, Green & Co., 1931. Price 12*s.* 6*d.*)

It is easy for the mathematician to feel hostility towards a work of this kind. It presents mathematics as a miscellany of hardly related topics; it permits itself the degree of unsoundness to which engineers are accustomed and by which they are undismayed; and it is entirely shameless about it. But the author is, no doubt, indifferent to the mathematician's views. He has written to supply a need, the need of the engineer to whom mathematics is a box of tools—rather awkward tools—and who wants them nicely arranged in compartments so that he can lay his hand on them and clearly labelled with a few precise instructions for use.

From this point of view the author's book is to be recommended. It is unusually comprehensive, clearly set out, and full of examples of a practical nature. Algebra, Trigonometry, Pure and Co-ordinate Geometry, Calculus, Differential Equations, Finite Differences, Harmonic Analysis—all are there, and the reader who is content humbly to take each tool as it is offered, and to use it according to the rules, will find himself at the end with all the mathematical equipment that any but a few exceptional engineers are likely to require. Here, then, is what the engineer wants, and he has been given it in generous measure.

And yet a doubt remains. Does the engineer really learn his mathematics better this way? Or would he, perhaps, use it more confidently if he understood it a little better? It is hard to say. But, whatever may be the ultimate answer, there can be no doubt that Mr. Low's book will find a present welcome both as a work of reference and as an examination textbook.

R. C. J. H.

The Taylor Series. An Introduction to the Theory of Functions of a Complex Variable. By P. Dienes, Reader in Mathematics in the University of London. [Pp. xii + 552.] (Oxford: at the Clarendon Press, 1931. Price 30s. net.)

The subtitle of a book is often more illuminating than the title itself. Hilaire Belloc once wrote a book whose title I have forgotten, but the subtitle sticks in my mind. It was seductively "called for the purposes of sale, Caliban's Guide to Letters," and in the vernacular, I fell for it. Incidentally, I repented me of my bargain.

The present work, called *The Taylor Series*, bears the clarifying subtitle, *An Introduction to the Theory of Functions of a Complex Variable*, and that is exactly what it is. It makes no pretensions to being a guide to the theory or application of particular functions, such as Bessel, Legendre, Hypergeometric, and so on, to which special works are devoted. It may be wondered why in that case the book runs to no less than 520 pages of reading matter. If it were possible to compel every *soi-disant* mathematician to study this work, many of them would get a wholesome shock. There are many well-paid mathematicians to whom even the ideas of Cantor are a closed book.

The fact is that the subject grows, it expands, it ramifies, it is alive. It is true that we have only one school of mathematicians in England; but they have no monopoly. The fundamentals of this subject are all continental in their origin, and from the European continent have come many of the major contributions of later date; so much so that a sensitive soul might be unduly depressed by the relative dearth of English contributions. But America has added her quota, and if French names and papers preponderate, well, as that naughty prelate, Laurence Sterne, remarked in a different connection, "they order these things better in France."

The moral is that unless one reads pretty widely and continuously the lapse of a few years finds one rather badly left. Dr. Dienes has placed English-speaking students and mathematicians under a debt of gratitude by an ably executed and thoroughly painstaking piece of work. With commendable generosity he is almost lavish in his acknowledgments of the assistance rendered by others; but the work is obviously the outcome of years of assiduous devotion to a difficult task, and the result is altogether admirable.

The author rightly states that no great mathematical armament is needed for the major portion of the book, and the treatment follows the lines of Cauchy and Weierstrass rather than Riemann; which is not to say that Riemann's ideas are ignored. There is a liberal supply of exercises for practice, and the author is wise in his mode of presentation. Too many writers present us with series of arguments to which nobody can refuse assent at any stage, only to leave us wondering at the end what it is all about. The sensation of letting a highly polished chain of reasoning slip through one's mind is pleasurable in itself. In the present work the author tells us quite explicitly in advance what it is he intends to prove. No one can pretend that the subject is easy reading; rather does the detailed study of it call almost for a special type of mind, even a special type of mathematical mind.

An efficient index and a fairly exhaustive list of errata are evidence of the care with which the work has been prepared, and when I add that there are no less than twenty-eight pages of bibliography, one sees that Dr. Dienes is as efficient a cicerone as preceptor.

F. E. Relton.

Trigonometry for the Practical Man. By J. E. Thompson, B.S. in E.E., A.M., Department of Mathematics, Pratt Institute, Brooklyn. [Pp. x + 204.] (London: George Routledge & Sons, 68 Carter Lane, E.C.4, 1931. Price 7*s*. 6*d*. net.)

Arithmetic for the Practical Man. By J. E. Thompson, B.S. in E.E., A.M., Department of Mathematics, Pratt Institute, Brooklyn. [Pp. xiii + 269.] (London: George Routledge & Sons, 68 Carter Lane, E.C.4, 1931. Price 7*s*. 6*d*. net.)

Algebra for the Practical Man. By J. E. Thompson, B.S. in E.E., A.M., Department of Mathematics, Pratt Institute, Brooklyn. [Pp. xviii + 291.] (London: George Routledge & Sons, 68 Carter Lane, E.C.4, 1931. Price 7*s*. 6*d*. net.)

The Calculus for the Practical Man. By J. E. Thompson, B.S. in E.E., A.M., Department of Mathematics, Pratt Institute, Brooklyn. [Pp. x + 321.] (London: George Routledge & Sons, 68 Carter Lane, E.C.4, 1931. Price 7*s*. 6*d*. net.)

It is difficult to understand the mentality that lies behind the production and publication of books such as these. Ostensibly they are "a group of books that make easy the home study of the working principles of mathematics," and "the series has been based on an entirely novel principle"; they are "specially written to meet the needs of the man who wishes to teach himself the subject in his spare time, and to apply the knowledge thus gained to his business, or trade."

Could any phraseology better engender hostility than this? In England at least, the practice of giving a practical trend to the mathematical studies of students who are not specialising in mathematics permeates our educational system, from the elementary schools upwards. The time is long past since that excellent mathematician, G. H. Bryan, used so justifiably to rail against the type of man who could only give his answers in "cosh minus ones." Our teachers, both elementary and secondary, not only learn mathematics, but they learn to teach it. The fruit of their accumulated experience, of their sympathetic understanding of the frequently quite trivial difficulties that beset the uninitiated, is that England can show as fine a set of textbooks in elementary mathematics as any country in the world.

The practical man frequently despises the mere theorician for his nebulosity and aloofness from reality, and if the theorician retaliates with a mild contempt for the practical man's uninspired adherence to mere rules of thumb, he does at least give the practical man credit for enough sense to come in out of the rain. If the practical man decides to learn some mathematics, he will first reconcile himself to the fact that he is in for some tough cerebration. His next move will be to enrol at the nearest technical or evening continuation school. In the unlikely event of these being too remote, he will take a correspondence course, some of which are undoubtedly excellent and admirably fitted to his needs. If he is flush of money, he might even engage a coach.

But here we have a publisher and an author working on an entirely novel principle in markets. They are going to cater for those practical men who are so unpractical as to regard themselves as a set of George Greens and teach themselves. Well, I give a publisher credit for knowing his business better than I can teach it to him; but I shall be surprised if many people part with three half-crowns for a book of less than two hundred and fifty pages on arithmetic; a book that deals in dollars and cents and fails to reach percentage till the last twenty pages; that tells them three barleycorns are one inch and thirty-six square miles are one township, but fails to tell them how the Egyptian sells his cotton or the Russian his corn. Nor can I see much call for a book on algebra that gives practically no information on how to manipulate a formula, though it gives the information that the name algebra

is derived from the Arabian word al-gebr, which means "the addition and subtraction of the same quantity on both sides of an equation"!

My sympathy goes out to the man who has to teach himself; but if he is wise, he will go to some well-established book that has gone through a sufficient number of editions to guarantee it being reasonably free from misprints. The present set are not particularly attractive, though they contain interesting historical notes. The best I can say for them is that, stripped of their dust-jackets, they look like novels.

F. E. RELTON.

PHYSICS

A Textbook of Thermodynamics. By F. E. HOARE, M.Sc., A.R.C.S., D.I.C., Assistant Lecturer in Physics at University College, Exeter. [Pp. xii + 271, with 46 figures in the text.] (London: Edward Arnold & Co. Price 15*s*.)

HERE is an entirely straightforward, clear, and comprehensive account of thermodynamics entirely devoid of any subtlety. It is the author's misfortune that of all the physical sciences thermodynamics is the most subtle, and it is to be feared that, on this account, his book loses much of its value for those who desire to attain a real appreciation of its perplexities. Those who must, of necessity, acquire a superficial knowledge of a large part of the subject will find here just what they require. The price of the book is probably justified by the excellence of its reproduction, but the sales would probably be greater if the publishers had arranged matters so that it could be sold at, say, 6*s*.

D. O. W.

Cours d'Optique. By G. BRUHAT, Professor in the Faculty of Science at the University of Paris. [Pp. ix + 756, with 657 figures in the text.] (Paris: Masson et Cie, 1931. Price 100 francs.)

IN the absence of any textbook in English dealing adequately with the modern science of optics in a manner suited to the needs of the student reading for honours, it is necessary to have recourse to books in other languages, and among these Prof. Bruhat's new book must take a very high place. It has three defects: firstly, owing to the arrangement of Physics courses in France, it omits all consideration of geometrical optics; secondly, it has no index; and finally, there are no references to original papers. This last omission is most unfortunate, not only because an honours student should be encouraged to refer to the classics of his subject, but also because nearly a quarter of the book deals with the results of modern spectroscopic research (including, for example, the Passchen-Back effect, the Stark effect, and the Raman effect), and here references with dates would seem to be essential.

The scope of the book can be indicated very briefly. Parts I, II, and III (pp. 1–287) deal with interference and diffraction in terms of the undulatory theory. Part IV (pp. 288–390) introduces the reader to the elementary phenomena of polarised light, and then deals with the electromagnetic theory for isotropic media (including dispersion). Part V (pp. 391–563) treats of anisotropic media and, as already stated, the remainder of the book is concerned with the various aspects of spectroscopy. Here, of course, the quantum theory is introduced; but the treatment of the theory of dispersion follows the lines laid down by Drude, and the author omits any account of the application of the methods of wave mechanics, rightly considering that, at present, these should be relegated to the post-graduate course.

The treatment throughout has the clarity that we have the right to expect from an experienced teacher. The diagrams are exceptionally good, and are provided whenever they can help to an understanding of the text (see, for example, the set of 12 figures illustrative of the use of Michelson's inter-

ferometer). The French is quite easy to read, and should present but little difficulty to the average student. The price of the book is very reasonable, and it deserves serious consideration by those seeking a good modern textbook on optics.

D. O. W.

An Introduction to Applied Optics. By L. C. Martin, D.Sc., A.R.C.S., D.I.C. Volume I, General and Physiological. [Pp. ix + 324, with 200 figures in the text.] (London: Sir Isaac Pitman & Sons, 1930. Price 21*s*.)

One of the difficulties met with by those who have to teach Geometrical Optics as a part of an advanced course on Light is provided by the gap which appears to separate the usual academic theory from the practice of the lens computer. It is true that a number of treatises dealing with the subject in its technical aspects are available; but these are not suited to the use of readers who want to know something about the design of optical systems without putting their knowledge to any immediate use. Dr. Martin's book fills this gap admirably and, while serving as an "elementary" textbook for the embryo specialist, it will be chiefly welcome as a link between the academic course and optical practice.

The book opens with an account of the general theory of optical systems; this is followed by enough of the theory of interference and diffraction to enable the student to understand the application of the wave theory to a discussion of the defects of the optical image. Next comes an account of the eye and of the phenomena associated with vision; a chapter on polarisation and double refraction; another dealing with the properties of glass, and finally a long discussion of the optical defects of the eye and their correction by spectacles.

The "General Theory," *i.e.* that usually treated under the heading "Thick Lenses," is dealt with in a notably simple manner on the lines used, *e.g.*, by Searle in his *Experimental Optics*. The sign convention adopted for lengths is that used in ordinary co-ordinate geometry, the angle convention is less familiar. These conventions are formulated on p. 17; but not until p. 40 is there any critical application of the distance convention, and here the author contents himself with the statement that "the equations below are in accordance with the sign conventions now in use (p. 17)." Both here and on p. 46, where the angle convention is needed, further explanation would be helpful in view of the notorious difficulties which signs provide for the student. There is an unimportant slip in Fig. 18, where the object and image points B, and B′, should be in line with the centre of curvature C of the spherical refracting surface.

Chapter IV, on the "Defects of the Optical Image," is undoubtedly the most important in the whole book for the student of physics. It presents in a clear and simple fashion—and in a reasonable space—the essential points of a very complex subject. The sine condition might perhaps have been treated at greater length, and the reason for adopting Conrady's somewhat complicated proof rather than a simpler one based on Hoskin's method explained. Furthermore, the word *coma* conveys (or has conveyed) many different meanings (*cf.* Eppenstein's article "Aberration," *Ency. Brit.*, 11th Edition), and a little discussion of these would have been helpful.

The chapter on physiological optics includes an account of contour acuity, Weber's law, glare, and, of course, definitions of the terms in common use. Since the book is intended for students of physics, such terms as *synapse* might well have been explained, and the section of the retina shown in Fig. 88 requires some indication of the scale, lest the reader unfamiliar with histological sections is left wondering how any light reaches the layer of rods and cones through the six layers above it.

The need for a book of this kind has been obvious for many years, and it is fortunate that this need has been supplied by the literary skill and expert knowledge possessed by Dr. Martin.

D. O. W.

Constitution of Atomic Nuclei and Radioactivity. By G. Gamow. [Pp. iv + 114.] (Oxford: at the Clarendon Press, 1931. Price 10s. 6d. net.)

The study of the atom, both by experiment and theory, has been the absorbing interest of physicists, and has met with such success that we appear to be on familiar ground, at any rate, in its outer regions. Recent discoveries may suggest that things are not all they seem, but the laws of electronic behaviour in the outer atomic region are known, and have stood the test of experiment. In contrast with this detailed exploration the nucleus remains a comparatively unknown territory. Thus an authoritative book on the nucleus is a welcome addition to atomic literature.

The word "constitution" in the title raises a hope which the book hardly fulfils. Nuclear constitution is not the important feature of the work. The volume is divided into four sections dealing respectively with the constituents and energy of nuclei, with spontaneous disintegration, with excited states, and with artificial transformation.

Of these the sections on disintegration and artificial transformation appear to us the most interesting.

The chief feature is the treatment of α-disintegration with the deduction of the Geiger-Nuttall law. This work, which is due to the author, ranks as one of the most brilliant and original applications of wave-mechanics, and is a striking confirmation of the view that the wave-function represents a probability.

References to experimental work are given in the text, but not to theoretical papers. This is to be regretted in a work of this kind.

Research upon nuclear constitution is proceeding actively, and we may hope that our increased knowledge will justify a further edition of the book at no distant date.

H. T. Flint.

Principles of Electricity. An Intermediate Text in Electricity and Magnetism. By Leigh Page, Ph.D., Professor of Mathematical Physics in Yale University, and Norman Ilsley Adams, Jr., Ph.D., Asst. Professor of Physics in Yale University. [Pp. xii + 620.] (London: Chapman & Hall, 1931. Price 21s. net.)

In our opinion, this book represents a worthy addition to those textbooks on electricity and magnetism which are usually to be recommended to students who are reading physics as part of a course for a pass or general B.Sc. degree. It may, however, be argued that the book is somewhat biased in favour of applied electricity, that it bears evidence that its subject-matter has been somewhat hastily assembled, and that from it have been omitted altogether certain important branches of electricity and magnetism. It should be added that vector notation is employed throughout.

Yet these possible criticisms are not sufficient to cause us to lose sight of the fact that the authors have made substantial efforts to give students an adequate introduction to the principles of electricity and magnetism, without leaving the more difficult theoretical aspects of their application severely alone. Thus, for example, when dealing with the magnetic field produced by a current flowing in a circular coil, the reader is not permitted to forget that expressions for the field at points off the axis of the coil are desirable. Again, the calculation of the self-inductance of a simple solenoid is more completely set forth in these pages than is usually the case in such textbooks.

There are a few remarks which should be borne in mind in contemplating

a future edition. The section on dielectrics is marked by clarity and conciseness, but we feel that, in view of the importance of the subject, more adequate reference to the experimental determination of dielectric constants should be provided, and that some indication, if only an indication, of the Debye theory of the temperature variation of the dielectric constants of gases and liquids is necessary.

A similar remark applies to the treatment of the theoretical aspects of paramagnetism and ferromagnetism. The theoretical treatment of diamagnetism follows the original theory given by Langevin in 1905. Perhaps the authors feel that more recent theoretical developments have not really helped in our understanding of the problem, but, at any rate, it is possible that some slight indication of their nature would be interesting and stimulating.

Very much attention is given to alternating-current circuits and to electrical oscillations. In fact, these chapters alone make the book a valuable supplement to existing textbooks. It is, however, surprising to find that no description of a cathode-ray oscillograph is given, although the Duddell instrument is described.

A valuable feature of the book is the excellent series of examples which are so frequently found, not at the ends of whole chapters, but at the ends of quite short sections, so that the student is automatically given helpful indications of the theoretical basis upon which particular problems must be tackled. Answers to the problems are also given.

The book is excellently printed and illustrated, and we commend it to the attention of all University teachers of physics.

L. F. B.

A Short History of Atomism. By JOSHUA C. GREGORY. [Pp. 258.] (London: A. & C. Black, 1931. Price 10*s.* 6*d.* net.)

WITH more than two thousand years of history behind it, the atom is easily the most venerable of the concepts of physical science. But its history, like that of other things ancient, is chequered; and for many centuries atomism was in disrepute. Since the seventeenth century, however, the atom has been in favour—more or less—because, as Mr. Gregory says, "science can neither believe wholly in it nor do without it."

Few readers will therefore fail to be interested in this history of atomism. After mentioning the tradition that asserts that Mochus or Moschus, a Phœnician, was the first atomist, Mr. Gregory goes on to trace atomism from the times of the early Greeks, Leucippus and Democritus, in the fifth century B.C., through the systems of Plato, Epicurus, and Lucretius, until it fell into disfavour towards the end of the second century A.D. During these seven centuries, however, many philosophers had already rejected atomism, because they could not admit a void in things and because a world richly endowed with qualities appeared to them inexplicable in terms of atoms without qualities.

During the Middle Ages atomism was practically abandoned, and it was not revived until the seventeenth century. Even then the atom returned only in disguise, as a divisible and deformable corpuscle in the Cartesian mechanism. But the acceptance of Descartes' system and the distinction made by Boyle and Locke between primary and secondary qualities prepared the way for speculations more frankly atomistic. Finally, the triumphs of Newtonian dynamics in the eighteenth century encouraged the replacement of corpuscles by indivisible particles, and at the end of the century Dalton's atomic theory was to some extent anticipated by William Higgins.

Then follows the detailed history of atomism in the nineteenth century, from Dalton's quantitative atomism to Sir J. J. Thomson's discovery of the electron. The concluding chapters discuss the various atomic models devised during the present century and the recent applications of quantum and wave mechanics.

Mr. Gregory's book is a valuable contribution to the history of science, and it will be read with profit by those whose interest in science is not confined within the narrow bounds of the present. Unfortunately, however, Mr. Gregory's style is heavy; and much of his writing is spoiled by the use of archaisms and words of his own coining.

D. McKie.

Dielectric Constant and Molecular Structure. By C. P. Smyth, Associate Professor of Chemistry in Princeton University. [Pp. 214.] (New York: The Chemical Catalog Co., 1931. Price $4.00.)

The publication of Delye's article on magnetism in the *Handbuch der Radiologie*, in 1926, was undoubtedly the cause of many new series of investigations. In particular, it was in that article that he gave an outline of his theory of the temperature variation of the dielectric constants of liquids, in which he introduced the conception of molecules endowed with permanent electrical moments. This conception had an important bearing on the problems of chemical structure, and the experimental determination of dielectric constants has become of considerable interest to physical chemists.

In the book before us the author has primarily considered the needs of the chemist, for whom he has provided a simple outline of Delye's theory, avoiding the more complicated mathematical treatment associated with the theory of anomalous electrical dispersion and the like. Consequently, the earlier chapters form an excellent introduction to the subject for those chemists and physicists who have not previously been interested in it.

In addition, the author gives a very readable presentation of the main experimental methods and technique now employed. He starts with the method devised by Drude, and describes the simple Lecher wire system. It is to be regretted that in this connection he writes of nodes, without specifying whether they are nodes of potential or nodes of current.

The Nernst capacity bridge, together with the technique adopted in the author's laboratory, are fully described. It is felt that more space could profitably be devoted to the resonance method, which Lattey and Davies have shown to be so effective with conducting liquids, and Appleton and Childs with ionised gases. Particular attention is, however, devoted to the heterodyne beat method.

Only brief mention is made of the molecular beam method of measuring electric moments. A short section is devoted to condensers or measuring cells, but only one diagram of such a cell is given; more diagrams would be helpful in this case.

Indeed, more than two-thirds of the book is occupied by the discussion of the relation of electric moment to molecular structure. The principles underlying this relation, as far as they are known, are clearly outlined. This portion of the book is, of course, mainly of interest to chemists. Many of the suggestions advanced are rather speculative, but they are stimulating and should lead to further researches.

A very useful list of electric moments is given in the appendix. References to original sources of information are everywhere adequately quoted.

L. F. B.

Dimensional Analysis. By P. W. Bridgman, Professor of Physics in Harvard University. [Pp. 113.] (New Haven: Yale University Press. London: Oxford University Press. Price 24s.)

This is a revised edition of a book which appeared first in 1922. The substance of it was given as a series of five lectures at Harvard University in the spring of 1920; only a few modifications have been made in this revised edition. The author has endeavoured to give a convincing exposition of his

views on the subject, but finds to his surprise that he has not succeeded in removing the subject out of the realm of controversy. The reason for this appears to be that on the special points which are essentially his own he is more than usually obscure. He doubts Fourier's requirement of homogeneity of dimensions, because it is possible to write for a falling body $s + v = \frac{1}{2}gt^2 + gt$; this equation is satisfied at every instant, and yet is not homogeneous. Such an equation, however, can never arise in a physical investigation; it is, in fact, two homogeneous equations arbitrarily rolled into one, each being *separately* satisfied. If this is recognised at the outset, much quasi-philosophical entanglement can be removed.

In brief, the book cannot be regarded as a happy exposition of the subject. Many of the pages simply lead to bewilderment. It certainly cannot be recommended to a beginner even if the price (24*s.* for 113 pp.) would not itself be prohibitive.

A. W. PORTER.

CHEMISTRY

Inorganic and Theoretical Chemistry. By F. SHERWOOD TAYLOR, Ph.D., M.A., B.Sc. [Pp. xii + 818, with 19 plates and 193 text-figures.] (London: William Heinemann, 1931. Price 12*s.* 6*d.*)

DR. SHERWOOD TAYLOR has here written a book that will establish his reputation as a sound chemist and a capable teacher. There are not many books to bridge the gap between higher certificate work and university courses, but those engaged in teaching science know quite well that the average successful candidate at the higher certificate examination is frequently too immature in outlook to plunge directly into a degree course. Dr. Taylor's experience at Holt and at Repton has enabled him to gauge with nicety the kind of treatment that will lead the young student to pass imperceptibly from the necessarily and properly juvenile chemistry of the schools to the adult study of the subject. As a work of reference on the shelves of the school science library, as a textbook for university scholarship candidates, and as the *vade mecum* of undergraduates reading for a degree, this book should find a wide sphere of useful service. Its general atmosphere is distinctly *au courant du jour*, although without sacrifice of critical appreciation of the past; in fact, the book as a whole unmistakably shows its author to have read chemical history both widely and deeply. There are some excellent plates, and an adequate index, but many of the figures in the text convey an impression of meanness and are not up to the general level of the rest of the production, which is high. There is a noticeable absence of misprints, though Phillip (p. 10) might be changed to Philip in the next edition, and there is no longer any sound reason for crediting Raymond Lully with "notable advances" in chemistry. More might usefully have been said about the theory of complete dissociation, since the theory of Arrhenius is now of mere antiquarian interest, but, in general, Dr. Taylor is to be congratulated on a fine piece of work, and his publishers on the very satisfactory *format*.

H.

Colloids. By ERNEST S. HEDGES, Ph.D., D.Sc. [Pp. vii + 272.] (London: Edward Arnold & Co., 1931. Price 12*s.* 6*d.* net.)

THE author in his preface states that this book has originated from lectures given at Bedford College in response to a wish for a non-mathematical textbook expressed by his students. He strikes an unusually sanguine note in some further remarks: ". . . There are, perhaps, few branches of physical science where it is possible to get a better mental image of the processes involved. This visual impression is to be gained, not by regarding the colloidal system as the unit, but rather by considering the processes from the point of view of the colloidal particle itself." This is perhaps a little too hopeful: the student may perhaps manage to form a "visual impression"

of the simplest type of suspensoid particle, but will find it anything but easy to do so with, say, gelatine particles in a sol, and almost impossible with the elements of a gel. To the latter systems, by the way, the author quite rightly devotes a larger proportion of his text than is usual.

On the whole, however, he proceeds on orthodox lines: an introduction is followed by chapters on colloids as polyphase systems; the formation of colloid particles; general characteristics of colloid systems; electrical properties of colloids; practical methods of colloid investigation; classification of colloids; stability of colloids. Only at this stage does he devote a chapter to adsorption, an arrangement which the present reviewer (who himself adopted it long ago) thinks quite sound, since the student of colloids wants to know, and can be told, a good deal about them without, or at any rate before, being confronted with a vast amount of experimental and theoretical matter, the bearing of which is none too clear. The author then deals with hydrophobic and hydrophilic colloids, non-aqueous colloids, and at some length with gels.

The language is easy and simple, without being loose, and the reader is not given too much in the way of theory or of " theories," if the distinction may be permitted. Occasional obiter dicta of a speculative nature may be questioned, as, *e.g.*, the suggestion on p. 157 that " the results [of viscosity measurements] may be affected in some cases by quite distinct processes, such as the adsorption of the colloid by the rotating cylinder in the Couette apparatus, thus increasing the roughness of the wall." That even macroscopic roughness has no effect in apparatus of this type was shown by Coulomb well over a hundred years ago, and an adsorption amounting to roughness would certainly have a far more disastrous effect in a capillary.

The book takes into consideration quite recent literature, as far as it comes within its purview. It is well printed, illustrated, and indexed, and forms a useful addition to the pedagogic literature of colloids.

E. H.

Theoretische Grundlagen der organischen Chemie. By WALTER HÜCKEL. Two vols. [Pp. xii + 410 and iv + 352.] (Leipzig: Akademische Verlagsgesellschaft m.b.H., 1931. Price 44 M.)

ORGANIC chemistry in the last fifteen years has undergone remarkable changes; at one time it seemed that little more remained to be done in this field except to elaborate the methods of the classical workers, to apply its technique to the study and synthesis of substances of biological importance and to prepare compounds of use in medicine, the arts, and industry. Instead there has been a great influx of new ideas and a subject which appeared exhausted now offers almost endless problems for solution. The introduction of the electron has produced a crop of theories to explain tautomerism, conjugated double bonds, substitution in the benzene ring and the formation of chelate compounds, and the experimental results born of these theories have shown how inadequate were the explanations of twenty years ago. Similarly stereochemistry, after a period of stagnation, has made great progress owing to a better realisation of the geometrical basis of optical isomerism. Many other examples could be quoted, but these are sufficient to indicate that textbooks of ten years ago which dealt with the fundamental notions of organic chemistry are now out-of-date. Prof. Hückel has attempted to remedy this state of affairs, and at present his work holds the field as the only modern textbook dealing with the principles, apart from the synthetic and descriptive aspects of organic chemistry. Practically the whole field is covered, and to students of organic chemistry to whom German does not present difficulties the book is almost a necessity.

In a short review it is impossible to deal with each subject, but it may be useful to indicate those mentioned. In Vol. I the principal topics are

stereochemistry and the strain theory, molecular organic compounds, including co-ordination compounds, free radicals, tautomerism, intramolecular rearrangement, the Walden inversion and allied changes, unsaturated compounds, and aromatic compounds. The fundamental ideas underlying the above phenomena are discussed and much recent work described. Vol. II deals with the relation between physical properties and chemical constitution, introducing most of the modern conceptions.

Excellent though the book is, it is not without its faults. The chapter on stereochemistry is somewhat old-fashioned in outlook, as the "asymmetric carbon atom" is invoked, and a lengthy explanation is given to show that both hexahydroterephthalic acids are internally compensated; a much simpler and sounder treatment is the consideration of the symmetry of the molecule as a whole.

Many of the modern developments in organic chemistry have arisen in the British schools, and Prof. Hückel does not differ from other continental authors in his comparative neglect of the work there done. In this connection one may mention that there is no adequate account given of the work of Thorpe and his school on the strain theory, most of the chapter on this subject being devoted to the theory of Sachse and Mohr. Similarly the application of electronics to organic chemistry by Lapworth, Robinson, and Ingold receives scant consideration.

O. L. B.

Colloid Aspects of Food Chemistry and Technology. By WILLIAM CLAYTON, D.Sc. (Liverpool), F.I.C., Chief Chemist and Bacteriologist to Messrs. Crosse & Blackwell, Ltd. [Pp. viii + 571, with 64 illustrations.] (London: J. & A. Churchill, 1932. Price 36*s*. net.

A TEXTBOOK dealing with the colloid properties of food-stuffs is long overdue, and the author is to be congratulated not only on supplying the deficiency, but for doing it in so eminently successful a manner. Anybody who has given the subject the least thought is well aware that Food Chemistry bristles with colloidal problems. To ascertain what work has been done on any particular aspect of the subject is, however, no easy matter, since the literature is very much scattered; the appearance of the present volume, however, clears away much of the difficulty of consulting original papers, since the author has accumulated a bibliography extending over close on 100 pages, for which labour he deserves grateful recognition; the papers quoted are culled from every kind of journal, and often from inaccessible research bulletins as well as from patent literature. The subject-matter is divided into thirteen chapters, dealing amongst other subjects with the chemistry of the proteins, agar and gums, cereal chemistry, emulsions, the colloid chemistry of milk and of sugar technology, jellies and jams, freezing and thawing of colloid systems and the treatment of water and factory effluents. Addressed primarily to the food chemist who has not specialised in colloid chemistry and physics, the book will nevertheless appeal to a very much wider public of chemists and of students who wish to ascertain for themselves illustrations of the practical applications of principles they have learned in the classroom or from textbooks dealing with the colloidal state. The book is so clearly written, and the subject-matter so well set out, that it may be opened almost anywhere and read with interest and profit by those having only a slight acquaintance with colloid chemistry, and might safely be put into the hands of those who have not previously studied the subject and would learn the principles involved from the applications presented; to assist the reader there is also a useful glossary of terms. The book is enriched by a number of illustrations and a wealth of tables and curves, and is very clearly printed; altogether a very excellent production.

P. H.

Physical Chemistry. By ARTHUR SUTCLIFFE. [Pp. vii + 373, with 54 text-figures.] (London: John Murray, 1931. Price 6s. net.)

THE author has designed his book for the use of sixth forms, and there is no doubt that he covers very effectively the ground required by the public examinations which sixth-form boys are required to take. The fact that the author has evidently had the answering of examination questions ever in his mind in writing the book will doubtless appeal to those who, under our present educational system, are not allowed to move very far from the examination syllabus. If it is felt that the shadow of the examination room hangs over this work, we must in fairness blame those who are responsible for imposing examinations rather than the author.

It is not to be understood, however, that this work is dry. On the contrary, the author has contrived while treating familiar subjects to handle them with touches of originality which give character to the work. In dealing with definitions, the author has generally shown good judgment in first giving an historical perspective and then indicating the extent to which recent work has led either to a modification, or a widening, of the concepts. As, however, these matters do require some personal judgment, it is hardly to be expected that everyone will be satisfied. For instance, the suggestion that in osmosis a force is operating which pushes the water molecules through the membrane, though it contains a partial truth, may, it is feared, lead to misconception, even though the author gives a perfectly proper definition of osmotic pressure in the following pages. Again, in discussing the electric charge on colloidal particles, no mention is made of the fact that the system as a whole is electrically neutral, a charge complementary to that on the surface of the particles being provided by ions in the dispersion medium. It is feared that the treatment given will tend to perpetuate the hazy misconceptions which are still very prevalent regarding the process by which colloidal particles are prevented from adhering to one another.

Generally speaking, the author has shown a good sense of proportion in deciding the amount of sub-atomics to include. But there is surely something wrong with Fig. 15 on p. 114, the explanation of which is also by no means lucid. In the interests of exactness, it might be well to replace Fig. 1, representing Amagat's results, by more exact curves, should the occasion arise. If the bottom of the figure represents the axis, the minimum value of P.V. is too low and the rising portion too straight for the 60° isotherm. It is also a pity that the imperfections in Andrews' curves reproduced in Fig. 2, which are now known to be due to traces of impurities, were not either pointed out or rectified. There is also bad draftsmanship in the 21·5° isotherm.

The book concludes with sixty examination questions selected from those set since 1920.

R. K. SCHOFIELD.

Chemistry, Life, and Civilisation. A Popular Account of Modern Advances in Chemistry. By HUBERT T. S. BRITTON, D.Sc., D.I.C., F.I.C., Lecturer in Chemistry, University College of the South-West of England, Exeter. [Pp. vi + 248, with 66 illustrations.] (London: Chapman & Hall, 1932. Price 10s. 6d. net.)

IN this book Dr. Britton describes, in simple language for the general reader and the beginner in chemistry, the part that chemistry plays in modern life and civilisation. The earlier and introductory chapters deal with the elementary principles of the science, and discuss matter, energy, chemical combination, acids, bases, salts, and some useful inorganic products and processes.

Then follow chapters on the sun and its relation to life, the atmosphere, the chemistry of the body, respiration, foods, digestion, vitamins, hormones, anæsthetics, clothing and paper, agriculture, fertilisers, the nitrogen industry,

metals and alloys, electric furnaces, and the generation of power. In this part of the book Dr. Britton pays special attention to the many and varied services that chemistry renders to the daily life of the modern civilised community by protecting its food and drink from adulterations and impurities, devising improved methods of cooking, heating, lighting, and sanitation, helping to detect the criminal poisoner, increasing the fertility of the land, preparing new drugs, medicines, and anæsthetics, fighting diseases, improving housing, clothing, transport, entertainment, and a thousand and one other things. He shows, too, by reference to modern advances, that chemistry is continually ministering to " the relief of man's estate."

Dr. Britton's book is well and clearly written and thoroughly up to date; and beginners in chemistry should derive much profit from the broadened outlook that it provides. The illustrations considerably add to its value.

D. McKie.

Industrial Chemical Calculations. By O. A. Hougen and K. M. Watson. [Pp. 492.] (New York: John Wiley; London: Chapman & Hall. Price 28*s*. net.)

The design and operation of chemical plant is an important aspect of chemical industry that has not until the last few years been adequately discussed in books available to the general run of technical men. Much of the data, too, held by the large industrial concerns is of an empirical character, and it is only recently that the quantitative aspects have been systematically studied and the data correlated. The book under review is a welcome addition to the literature. The authors (professors of Chemical Engineering at the University of Wisconsin) give a full and adequate discussion of those principles of physics and chemistry most important industrially. The discussion of each subject is followed by a concise development of methods for handling such industrial problems as may arise in this particular field. Typical problems are solved in detail, and batches of problems are given for the reader to do. This method should avoid superficial memorisation. A large range of subjects is treated, and includes, amongst others, Calculations on Gaseous Mixtures, Crystallisation, Thermophysics, Thermochemistry, Distillation Equilibria, and Chemical Equilibria. A relatively large amount of space is devoted to weight and heat balances, and detailed balances are given for both a chamber sulphuric-acid plant and a blast furnace. The unit operations of chemical engineering are not dealt with. It is unfortunate that absorption and related phenomena are neglected, as these are attracting attention at present. As a whole the book places considerable aid before men training for technical positions in chemical and metallurgical industry, whether as chemists or engineers. It should indeed indicate to each of these two groups of professional men that chemical industry is not dependent on either of them alone, but depends rather on a careful blending of their respective functions.

C. P. Warden.

Physical Chemistry. An Elementary Text, primarily for Biological and Pre-medical Students. By Louis J. Gillespie. [Pp. ix + 287, with 43 text-figures.] (The McGraw-Hill Publishing Co., Ltd., 1931. Price 16*s*. 6*d*. net.)

It is stated, both in the subtitle and the preface of this book, that it is intended for the use of biological students. In no sense is it a textbook of physical chemistry, since it has no mention of atomic or molecular structure, and but the slightest references to the mechanism of chemical change; so, while it might be arguable that many biological students would prefer a more liberal treatment of their chemical background, Prof. Gillespie has kept rigidly to his point, and written his book around the central theme of equilibrium.

Some of the chapters in the book are good; for example, the reviewer found those on "Electrical Conductance," "The Law of Mass Action," and the section on its application, "Buffers and Titration Curves," and "Oxidation and Reduction Potentials" to be elementary but useful, with the simple theory detailed but not diffuse. Other parts of the book have less to recommend them: one wonders whether a rather bald and formal treatment of the Phase Rule is really suitable as Chapter I of such a book; if a judicious use of the calculus is not more helpful than the assumption of ignorance of its notation by the student; and above all, if a biological student should be encouraged to regard physics, chemistry, and biology as separate studies? The last impression is fostered in the book by the use of such phrases: "This is proved in Physics" (p. 258); "Sodium and calcium have long been regarded as antagonistic in biology" (p. 37); "Physical chemists usually call the osmotic pressure the osmotic pressure of the solution, biologists often call it more explicitly the osmotic pressure of the dissolved substance. . . ." (p. 79). Speaking of "division of one concrete number by another," it is stated that "it is permissible in natural science, and if 'permitted' in arithmetic it would greatly facilitate . . ." (footnote, p. 14); "Not only chemically definite amphoteric electrolytes show an isoelectric point . . . but also various proteins, colloids, and suspensions of bacteria and other biological material" (p. 210). Such sentences are frequent and become irritating.

Another quotation will illustrate the author's attitude towards formal derivations, an attitude for which there is much to be said, but which should be adopted *in toto* or not at all: "Other liquids are believed to continue to spread out until the layer is only one molecule deep. Such a case is not a suitable one for the purpose of deriving Antonoff's rule, as the surface tension of a film one molecule deep, if indeed it is a fit subject for discussion, is very likely not the same as that of a thick layer" (p. 34); to which the author adds the footnote, "Experienced students do not ordinarily consider derivation as proofs of fact, but rather as aids to the understanding of facts and their mutual relations." Throughout the book are to be found a number of expressions for which a mathematical derivation is given, and perhaps an equal number are quoted with no attempt at proof; thus a good explanation of the mass action equation is given, and the Clapeyron equation is only quoted; the electromotive force of cells is discussed in fair detail, but the Gibbs-Helmholtz equation receives no mention. Even at the risk of alarming a nervous student with no knowledge of the calculus, the average student would probably benefit by a deduction of these two fundamental laws. The author's use and explanation of activity in place of concentration are very much to be welcomed.

There do not seem to be enough concrete examples of the application of the subjects discussed to the subjects taught in a course on, say, physiology. The reviewer, enquiring what should be taught to a medical student, was told that as good an object as any was to enable the student to understand Bayliss's *Principles of General Physiology*; a very reasonable criterion, but one by which the book does not succeed. The omission of any account of photochemical or autoxidation processes, such as may occur in a cell, also seems unfortunate. But probably no agreement will be reached as to what a premedical student should be taught, and to attempt to produce a textbook for him must be one of the most thankless of tasks.

O. H. W.-J.

Hydrogen Ions, their Determination and Importance in Pure and Industrial Chemistry. By HUBERT T. S. BRITTON, D.Sc. Second Edition. [Pp. xvi + 589, with 124 text-figures and 117 tables.] (London: Chapman & Hall, 1932. Price 25*s*. net.)

A SECOND edition of this book has been required in little more than two years. This is not surprising, because it has the merit of being particularly

useful in the first part, devoted to the theory and practice of pH determination, and particularly interesting in the second part, in which the author has turned his attention to the manifold necessities in industry of hydrogen-ion control.

In the second edition, seventy pages have been added, and three new chapters. Of the latter, much the most important is that devoted to "Modern Theories of Electrolytic Solution" (the others are entitled "The Precipitation of Sulphides" and "The Hydrogen Ion Concentration of Hens' Eggs"), and special commendation should be given to this lucid if elementary account of modern theories, and to the restraint exercised in dealing only with those theories which can relevantly and properly be discussed in a book belonging to a series of monographs on applied chemistry. The whole book is an example of judicious mixing of theory and practice, enough of the former always being given to explain the principles of the latter; the description of experimental methods being clear and complete, but not overburdened with refinements of technique which are always better found when needed by reference to the original papers. For these reasons it is an admirable book for anyone unaccustomed to making pH determinations, and requiring to make them rapidly and satisfactorily.

The reviewer is sure that the second part of the book will be of great interest to many; but is a little uncertain whether specialists in the subjects there referred to might not need to consult specialist treatises, and if this is the case, and this section is meant for the general reader, whether some more condensation and selection might not have been possible. The author certainly justifies his reference to the importance of hydrogen ions in pure and industrial chemistry. The style of the book is excellent.

O. H. W.-J.

GEOLOGY

Engineering Geology. By H. Ries and T. L. Watson. Fourth Edition. [Pp. viii + 708, 88 plates, 253 figures.] (New York: J. Wiley & Sons; London: Chapman & Hall, Ltd., 1931. Price 25*s*. net.)

The third edition of this well-known textbook was reviewed in Science Progress, July 1926, p. 155. A number of additional references have been given and old ones have been brought up-to-date. The most extensive alteration is the insertion of a new chapter on the geology of reservoirs and dam sites (pp. 446*a*–446*t*), a branch of engineering geology which is of much importance, and which has been somewhat neglected. A number of recent reservoir failures in the United States and elsewhere has focused attention upon this subject. The topics briefly and well treated in this new section are the geological facts bearing on the watertightness of the reservoir basin, and the geology of the site of the proposed dam in relation to the safety, effectiveness, and cost of the structure. The latter is perhaps the most important consideration, for more disastrous consequences follow from the failure of a dam than from the leakage of a reservoir basin.

The illustrations, as in the last edition, are magnificent. We are glad to see that the discrepancy which existed in the third edition between plan and section in Fig. 117 has now been dealt with; but the broad zone of fault-breccia in Fig. 64 (p. 102) is still bordered by undisturbed strata. This book holds its place as the best treatise on engineering geology for English-speaking students.

G. W. T.

Elements of Engineering Geology. By H. Ries and T. L. Watson. Second Edition. [Pp. vii + 411, 276 figures.] (New York: J. Wiley & Sons; London: Chapman & Hall, Ltd., 1930. Price 18*s*. 6*d*. net.)

This book is a condensation and simplification of the larger work reviewed above to meet the requirements of a briefer and more elementary course in

engineering geology. It is, however, not a replica in miniature of the larger book, for parts of it have been rewritten, and the relative proportions of space allotted to the various topics are different. The arrangement of the matter has been changed, and the chapters on building-stone, limes, cements, and plasters, clays and clay products, coal series, petroleum and natural gas, and road materials, have been omitted, although references to these matters are scattered through the text. The result is a book which we think is even better adapted to the work of the ordinary class in engineering geology than the larger work. The illustrations, while naturally fewer than in the more extended treatise, are just as fine and as well selected.

In comparison with the first edition (which was not reviewed in SCIENCE PROGRESS), this work includes two new chapters, one on the geology of reservoirs and dam sites, and one on historical geology, both of which are identical with the corresponding chapters in the larger work.

Notwithstanding the fact that the book caters primarily for the American student, its statements of principles and illustrative examples will prove of equal value to the student on this side.

G. W. T.

Elementary Economic Geology. By H. RIES. [Pp. vii + 360, 29 plates, 136 figures.] (New York: J. Wiley & Sons; London: Chapman & Hall, Ltd., 1930. Price 18*s*. 6*d*. net.)

THIS book has been condensed from the author's larger book entitled *Economic Geology*, the last edition of which was reviewed in SCIENCE PROGRESS, April 1931, p. 713. The aim has been to make the work short enough for a one-term course in the subject. To that end more emphasis has been placed on principles at the expense of space devoted to the description of individual localities, illustrative examples, and technological details. A chapter on subsurface waters in the larger work has been omitted in this. The illustrations, as usual in this class of work, are excellent. This book may be recommended to the student of economic geology, although the type of student for whom it is intended would appear to be much more numerous in America than in this country.

G. W. T.

The Study of Rocks. By S. J. SHAND, D.Sc., Ph.D., F.G.S. [Pp. xi + 224.] (London: T. Murby & Co., Ltd., 1931. Price 6*s*. net.)

OUR high appreciation of Prof. Shand's lively, interesting, and valuable little book on the study of rocks is hardly lessened by our doubt as to what constituency the book is really addressed. Mostly it seems to cater for the elementary student, but statements such as "the lopolith is a saucer-shaped intrusive body occupying a tectonic basin" (p. 16) are introduced at a stage when the elementary student can hardly be expected to know what a tectonic basin is. Other statements requiring an advanced standard for their appreciation also occur, but the general treatment is well within the capacity of the elementary student.

After an introductory chapter on modes of study of rocks, which contains a strong plea for more chemical analyses and their fuller use, the igneous rocks are dealt with in seven chapters occupying 120 pages. The sedimentary rocks, classified as organic residues, solution residues, crystalline rock-residues, and cryptocrystalline and colloidal rock-residues (clays, mud-stones, shales, etc.), are then treated in five chapters occupying 48 pages. Finally the metamorphic rocks, classified as mylonites, hornstones, and crystalline schists (with four subgroups based on the ratio of alumina to bases in the characteristic minerals) are disposed of in two chapters and 35 pages. Prof. Shand is at his best in dealing with the igneous rocks; he is not quite so happy

in his treatment of the sedimentary and metamorphic rocks, although the material throughout is good, fresh, and well arranged.

With regard to the igneous rocks, we can agree with Prof. Shand's strictures on nomenclatorial redundancies, while recognising that the evil has much abated since the last great spate of new names in Lacroix's *Minéralogie de Madagascar*. His statement that the nepheline-syenites are more common than the true syenites (p. 125), which is no doubt coloured by his African experience, may be challenged in view of the abundance of soda syenites if not of potash syenites. And was not the original shonkinite (p. 84) a thoroughly under-saturated rock? Prof. Shand would prefer to regard the common augite- and hypersthene-bearing andesites (in the Rosenbuschian sense) as basalts on the ground that they carry "much pyroxene" (p. 98); but chemically these rocks are very different from basalts. A recent computation from 114 analyses (*Discovery Reports*, vol. III, 1931, p. 195) shows that the average andesite rich in augite and hypersthene contains 59·2 per cent. of silica, with 14·3 per cent. of quartz in its norm, while the femic constituents including the pyroxenes only amount to 19·8 per cent.

"Rock-flour" (p. 141) as synonym for crystalline rock-residues is highly misleading, and does violence to the King's English as a scientific misappropriation of a popular term. It would apply better to Prof. Shand's Class IV of sedimentary rocks—Cryptocrystalline and Colloidal Rock-residues; but even these are only partly composed of rock-flour, if by this term is meant rock-material ground to the finest powder.

Prof. Shand approves, and rightly, of Goldschmidt's classification of metamorphic rocks based on their mineral characters, but makes no mention of Eskola's facies classification which carries the same principle even farther. He introduces a good new term, *marmorite*, to replace the cumbrous circumlocution calc-silicate-hornfels.

Prof. Shand has accomplished the almost unprecedented feat of writing a textbook on petrology containing not a single illustration and only one diagram; and the fact that the reader does not feel any necessity for illustration is a testimony to the quality of the writing. The above criticisms of detail should not be misconstrued; they are but spots on the sun of the general excellence of the book. This textbook is so good that it should be in the hands of all students of petrological science and of its practitioners.

G. W. T.

The Principles and Practice of Geophysical Prospecting, being the Report of the Imperial Geophysical Experimental Survey. Edited by A. B. Broughton Edge and T. H. Laby. [Pp. xiii + 372, with 261 figures.] (Cambridge: at the University Press, 1931. Price 15*s*. net.)

This book is the record of two years' experimental work in Australia on investigations of the applicability of the four principal geophysical methods—gravitational, electrical, seismic, and magnetic—to the location of mineral deposits and underground structural features. It is a handsome volume, carefully produced and well-printed. The field parties, although not very adequately equipped, carried out extensive work in the six Australian States, under the leadership of Mr. Broughton Edge, and his deputy Dr. E. S. Bieler, who most unfortunately died suddenly during the progress of the Survey. Both these gentlemen were great authorities in relation to the electrical methods, and it is therefore not surprising to find these methods forming the principal feature of the work undertaken.

Certainly on the electrical side the report is the most authoritative statement of theory and practice that has yet been published, and will be regarded as the standard work at any rate for those desiring to read in English. The other sections, although not so outstanding or complete, will nevertheless be

found useful also, for they contain abundance of those details of field procedure and instrument manipulation which are so often neglected in publications on the subject.

The arrangement of the volume is for most purposes convenient, consisting, as it does, of two more or less distinct parts. In the first we find chapters dealing with the essential principles of the various methods, but devoted mainly to field practice and the interpretation of the results obtained. Part II contains fuller treatment of the theories of the methods and of the instruments employed in them. Roughly, we may take Part I as being for the geologist and Part II for the physicist.

There is little that calls for criticism, but there should perhaps be noted the frequent specification of the units of measurement after the symbol in expressing a physical quantity, as, for example, "a mass of *m* gm." This is always unnecessary, and sometimes definitely incorrect, as on p. 280, where we find the equation—

$$H_0 = 1{\cdot}13 \frac{i}{a} \text{ gauss},$$

and later: "If $i = 3$ amps and $a = 500$ m, then $H_0 = 6{\cdot}8 \times 10^{-3}$ gauss." The symbols i and a are mere numbers in the first statement and physical quantities in the latter, which is accordingly inconsistent with the first. It is certainly to be preferred that the symbol should itself include the unit.

A certain looseness of expression also sometimes appears, as in the statement on p. 310, with reference to the topographical corrections necessary in gravity surveying, that "the assumption is then made that the variation of height from one circle to the next in any given azimuth is *proportional to the radial distance from the station.*" [The italics are the reviewer's.] What is really meant is that *within the limits of the interval between two adjacent circles*, the height of the ground is a *linear function* of the distance from the station, actual proportionality, which would be absurd, not being involved. But the rarity of such errors reflects the care and skill with which the editors have done their work.

It cannot be claimed that the methods employed in the Survey were uniformly successful. This was, indeed, scarcely to be expected, for the purpose of the expedition was to test methods and report without bias upon them. Notable successes have, however, been obtained, and, what is at least equally important, the work under the stress of field conditions has indicated definite lines of improvement in the construction of instruments and in field procedure, which are likely to lead to still greater achievements in the future. Unfortunately, the report has appeared just at a time when the large expense of these further investigations cannot be undertaken, but there can be little doubt that before long the results of this Survey will serve as a new starting-point in Australia and possibly in other fields.

A. O. RANKINE.

BOTANY

Plant Physiology. With reference to the Green Plant. By EDWIN C. MILLER, Ph.D. [Pp. xxiv + 900.] (London: McGraw-Hill Publishing Co., 1931. Price 35*s*. net.)

THIS book, although its title suggests that it is a comprehensive textbook of the physiology of the green plant, is largely confined to the metabolic aspects of physiology; the phenomena of irritability and movement, in which such great advances to our knowledge have been made during recent years, are not considered.

In his preface the author states that it has been his intention to summarise the more important findings of English, American, and Continental plant physiologists. As regards plant metabolism, it may be claimed that the

author has largely succeeded in his purpose, and the book contains summaries of an enormous number of plant physiological works. For this reason it cannot fail to be of use to advanced students of physiology. On the other hand, the very wealth of citation gives the work in places the appearance of a mere collection of abstracts, with the consequence that principles are apt to be obscured in a mass of detail. Thus in the chapter on Respiration in Plants the results obtained by numerous workers on the effects of temperature, moisture, injury, kind and age of tissues, anæsthetics, concentration of oxygen and carbon dioxide, various salt solutions. light and electricity, are all detailed, but nothing is said of the important work of Neuberg on yeast fermentation and its bearing on the mechanism of respiration, while, although a passing reference is made to Blackman's recent work on respiration, no account is given of his theory of the respiratory process.

The essence of the matter probably is that the author has attempted to treat his subject as one would do in writing a monograph, and plant metabolism is too large a subject to be treated in this way in a single volume, even in one of 900 pages. In the opinion of the reviewer a more satisfactory result might have been achieved had the author attempted more selection from the great mass of material available, with the object of emphasising the principles of the subject. However, Prof. Miller has certainly rendered plant physiologists a service by bringing together so much information on the physiology of the green plant.

W. S.

Flora of Surrey. By Charles Edgar Salmon, F.L.S. Edited by William Harrison Pearsall. [Pp. 688, with 9 plates and 2 maps.] (London: G. Bell & Sons, Ltd. Price £2 2s.)

In spite of the inroads of the builder, Surrey can still boast of a wide and varied flora, due partly to the geological peculiarities of the county, and the fact that it is so rich in commons. The late Mr. Salmon's account of the flowering plants, ferns, and Characeæ of the county he knew so well has been eagerly awaited by field botanists for many years, and will now form a welcome addition to their libraries.

The book opens with an account of the Topography and Climate of Surrey by Mr. W. F. Taylor. This is followed by an able sketch of the Geology of the county by Miss M. C. Crosfield, F.G.S., the value of which, however, is somewhat lessened by the fact that it was written in 1920, since when much important and detailed work on the subject has been done throughout the country. The introductory part of the book also includes an "Outline History of Botany in Surrey," by the late Prof. G. S. Boulger, F.L.S.

The flora itself contains particulars relating to over 1,250 plants. The stations given in the earlier part of the book (up to p. 550) are very numerous. In the latter part, printed after Mr. Salmon's death, the editor has omitted many records now only of historical interest, and has condensed the matter very considerably. This unevenness is regrettable. If the numerous early records given in the first part of the book are of value, similar records for the species dealt with in the latter part would have been equally valuable and should have been included. If, on the other hand, records of this type have ceased to possess living interest, then the reader's time and money are being wasted by their inclusion in the early part. However, these 550 pages had been printed before the author's lamented death, so that no condensation of the matter contained in them was possible.

As to the records themselves, field botanists who know Surrey will find that few, if any, stations for plants of interest have been omitted, at any rate in the first 550 pages.

In the latter part of the book, however, all Surrey botanists will be surprised at the omission of the station "between Tot Hill and Mickleham" for

Lilium Martagon L., since this place appears to be well known—too well known, indeed, for it is difficult ever to find a plant in flower there.

Many of the stations are given in very guarded language, with a view, of course, to save rare plants from extermination by rapacious collectors. Nevertheless, this cautiousness will irritate field botanists who desire to see some of Surrey's floral treasures in their native haunts.

The Byfleet station for *Veronica triphyllos* L. is given, but the plant is not numbered, Mr. Salmon not having considered it to be indigenous to Surrey. The recently discovered *Bromus brittanicus* I. A. Williams is not mentioned.

A "Revision of the Genus Rosa," by Lieut.-Col. A. H. Wolley-Dod, is included at the end of the book.

H. S. Redgrove.

Selecta Fungorum Carpologia of the Brothers L. R. and C. Tulasne. Eng. trans. by W. B. Grove, M.A. Edited by A. H. R. Buller and C. L. Shear. Vols. I–III. [Pp. 66–758, with 61 plates.] Oxford: Clarendon Press. Price £6 6s.)

The original of this work was published by the Tulasne Brothers in the period from 1861 to 1865, and was mainly concerned with establishing the then novel idea that some species of Ascomycetous fungi were of a polymorphic character with respect to their reproductive organs. The remarkable capacity of Louis Tulasne, the elder brother, as an observer, and his capability in recording his observations in exact description, were peculiarly suited for the development of a point of view that was of a revolutionary character. Moreover, his younger brother Charles was a highly skilled draughtsman, as the beauty of the illustrations to this work sufficiently attest, and was exceptionally gifted as a microscopist. The collaboration of these two talented mycologists resulted in the production of the *Selecta Fungorum Carpologia* which contains detailed descriptions of a large number of Ascomycetous fungi, whilst the engravings on copper, at once beautiful and exact, presented nearly 1,100 separate drawings on the 61 plates.

The present volumes are a translation of the Latin text of this historically important work by Mr. W. B. Grove, who, in rendering the original into English, has nevertheless succeeded in capturing a certain charm of expression so often lacking in translations. This *magnum opus* is not only a monument to the memory of the authors, but a striking illustration of the extreme value of the intensive study of particular species as the basis for fundamental generalisations. The attitude of the Tulasnes is well shown by a quotation from the preface, in which the authors write, "To understand any fungus, however minute and lowly, often demands of the mycologist long months or even years of assiduous labour. Yet these able investigators did not grudge this demand on their valuable time, knowing it to be the surest route for real scientific advance." To adopt a Yorkshire expression that should not fall into disuse, as it embodies a nuance of meaning for which we have no other exact equivalent, the brothers Tulasne knew this to be the "gainest way" for progress.

This English translation has been edited by Prof. Buller and Dr. C. L. Shear, who record their indebtedness to Dr. H. A. Kelly, Mr. J. Richardson, Mr. M. Steinkopf, Mr. T. B. Macaulay, and Mr. E. W. Mason, through whose generosity this publication has been made possible. The editors have provided the necessary synonymy rendered essential by the modern changes in nomenclature. The gratitude of mycologists in particular and of botanists in general will extend to all those concerned in the task of rendering this extremely rare and expensive work available for their consultation. It only remains to add that the collotype reproductions of the original plates, the excellent typography, and the text as a whole, are worthy of the high standard of the Clarendon Press.

E. J. S.

ZOOLOGY

Emigration, Migration, and Nomadism. By WALTER HEAPE. [Pp. xii + 369.] (Cambridge: W. Heffer & Sons, 1931. Price 12*s*. 6*d*. net.)

THE late Dr. Walter Heape was a distinguished pioneer in the field of reproductive physiology, and this posthumous work develops certain ideas about the migrations of animals in relation to nutritive and reproductive needs which arose out of his earlier researches. The book has been edited by Dr. F. H. A. Marshall (whose volume on the *Physiology of Reproduction* has become a classic) and it has thereby benefited by a thoughtful preface and occasional footnotes relating to recent developments in the subject.

The title of the book seems to us a little misleading, for it suggests at first sight that the book is about human emigrants and nomads; actually it deals with the whole animal kingdom.

The subject of the migratory movements of animals is an extraordinarily interesting one, and the time is becoming ripe for a comprehensive treatment of it. Hitherto, only the migration of birds (and to some extent fishes) has received anything like adequate attention. Dr. Heape's book may be regarded as a first attempt—and a very valuable one—to deal with the subject as a whole. He has succeeded in collecting together from many sources a most interesting body of facts, and for this alone the book is meritorious.

Naturally, it is impossible in such short compass to cover the whole field in detail, and Heape's treatment of parts of the subject is somewhat scrappy. A recent German writer (Scheuring) required many hundreds of pages for a summary of the data relating to fish migration alone, and even this was not completely up-to-date. It would not be difficult, then, to pick holes in Heape's data and to point out omissions. The Bibliography, though useful, is obviously very incomplete.

In spite of some minor failings, the book is of importance as linking up many scattered facts of ecology, behaviour, and physiology, and bringing out the essential problems raised by the migratory movements of animals—most of them fundamental, and all very difficult. Of particular importance is Heape's starting-point—the conception of homes and territories. This idea was brought into prominence by Elliot Howard's work on the breeding-territories of birds, and it has proved very valuable in interpreting bird behaviour. It will probably be found to be of much wider and more general application, and it deserves closer attention and study by animal ecologists. Heape has brought together much interesting information about the existence of territories, held by individuals or pairs or groups of animals for the purpose of ensuring food and refuge for themselves and their offspring.

Of importance too are the clear distinctions drawn by Heape between various types of migratory movement. Thus he distinguishes between emigration and migration. Emigration is a mass movement away from the home territory which is followed by no return; in migration there is a return to the area from which the movement started—as, for example, in the migration of birds. The classical case of mass emigration is, of course, the lemming in Norway, where in certain years, following an enormous increase in numbers, whole populations emigrate to the westward (leaving very few behind), and perish in hordes. Heape thinks that the lemming move to the west instead of spreading north and south because this is the only direction in which they can travel without violating the territory of neighbouring groups.

Three kinds of migration may be distinguished—alimental, climatic, and gametic. Of these the first two are for the welfare of the individual; the third is for the continuance of the race, and it is probably initiated by gonadic secretions. Nomadism is the habit of wandering over a territory of wide extent; the wanderings may be irregular, or the territory may be covered

in a systematic manner, governed usually by climatic conditions. The moose, for example, shows this nomadic habit.

Heape suggests that the physiological stimulus to gametic migration is the same gonadic secretion which is responsible for the growth of the secondary sexual characters prior to sexual activity. He supposes also that reproductive activities are stimulated by a vitamine absorbed with the food. Dr. Marshall points out some difficulties attaching to these views. The value of the book seems to us to lie not so much in the particular theories advanced as in the correlation attempted between ecological or "natural history" data and physiological facts. It should have a stimulating effect upon research.

E. S. Russell.

Biology and Mankind. By S. A. McDowall. [Pp. xviii + 229, with 46 figs.] (Cambridge University Press, 1931. Price 6s. net.)

Mr. McDowall has thought fit to give to the public what has been prepared for lectures to senior pupils at Winchester. We do not think the public need be grateful. The book is not remarkable for lucidity or accuracy or judiciousness; it perpetuates several ancient errors, and is full of over-confident statements, derived no doubt from an uncritical reading of semi-popular books on heredity and eugenics. The author is too much concerned to promulgate his own social and political views. One cannot doubt the sincerity of his attack upon democracy, and one may even agree with it to some extent, but it seems to us out of place in a book which purports to give the general reader an idea of modern biology. A scrappy account of the evidence for evolution, and of theories of evolution, a lengthy treatment of the mechanism of Mendelian inheritance, and many pages of eugenic propaganda do not seem to us to constitute a satisfactory introduction to biology either for the student or for the citizen.

E. S. Russell.

Textbook of General Biology. By Prof. Waldo Shumway, University of Illinois. [Pp. viii + 361, with 194 text-figures.] (London: Chapman & Hall, Ltd., 1931. Price 15s. net.)

All connected with university teaching recognise that there is a tendency, more or less well marked, for the courses in various departments to be so designed as to produce specialists in their own departments of knowledge. Thus the successive courses in the departments of Botany and Zoology from the beginning aim at providing a training for professional Botanists and Zoologists. Many students take only the first course in either or both of these subjects, and so present a problem in departmental organisation. It may be met by ignoring their requirements, and including them with the other group or by modifying the first course to suit their needs, and to this extent sacrificing those who desire to specialise. Neither of these is satisfactory. The author of the present work states in his preface that "this book has been written because of a feeling that there is a place for a fresh survey of modern Biology especially designed for those who do not plan to specialise in either Botany or Zoology." This is the better way, and fortunate is the department whose staffing allows this solution of the difficulty.

A textbook with this end in view should, in the first place, contain judicially chosen material well arranged and, in the second, since presumably there will be no subsequent opportunity for the student to correct initial mistakes in the light of further knowledge, the text must be accurate and clearly written.

The book commences with a brief account, structural and physiological, of a vertebrate animal, the frog, and a flowering plant, wheat. This is followed by chapters on the metabolism and behaviour of the cell and the part it plays in reproduction. Then follow chapters on Heredity and the gene, Ecology

and the Community, the Evolution of Species, the Plant Kingdom (a general survey), the Animal Kingdom (a general survey), and Applied Biology—the last being subdivided into Man's Place in Nature, Medicine, Public Health and Hygiene, Eugenics and Euthenics and Agriculture, Agriculture and Conservation. Two appendices deal with a glossary of technical terms and classifications of the Plant and Animal Kingdoms.

No two biologists will agree on what should be included in or omitted from a course of this sort nor of the relative amount of space that should be devoted to the different sections. On the whole the present book has been well planned, and its subject-matter carefully chosen. Too much attention perhaps has been devoted to theories instead of facts. After all, the fundamental training of a science is not the discussion of various theories, however interesting that may be. Apart from that the course outlined appears more satisfactory than several previous attempts to meet the same need.

The matter is clearly and succinctly put, but unfortunately the text is marred by a number of mistakes. For example, on p. 5 " binomial " instead of binominal or binary, the terms employed in the international code; the diagrams of the arterial and venous systems of the frog on pp. 15 and 16 are so inaccurate that even a beginner should be struck by the mistakes; on p. 24 the number of phalanges in the fourth digit of the foot is wrong, and does not agree with the diagram on p. 28; on p. 37 the pronephric duct in the male frog is labelled " oviduct "; on p. 124 it is stated that Harvey is responsible for the aphorism " omne vivum ex ovo," which occurs nowhere in his writings; on p. 294 it is stated that the Cyclostomata " lack true jaws," and four lines lower that they have no " teeth on the jaws," a mystery to a beginner surely; on p. 295 it states that the four species of living Dipnoi are found in branches of the Nile and the Amazon; no mention is made of Neoceratodus from Australia, nor of the fact that Protopterus is found over a large area of western equatorial Africa; on p. 303 we read " Australia has a fauna which is exclusively marsupial so far as mammals are concerned," this shortly after a statement that monotremes are found in Australia, and in face of the quite appreciable number of indigenous eutherian mammals, etc.

In spite of these blemishes it is a book to be read by those interested in this type of course, for it presents a number of new suggestions and methods of treatments.

C. H. O'D.

The Irish Wolfhound. A short historical Sketch. By PHYLLIS GARDNER. [Pp. 253, with over 100 illustrations.] (The Dundalgan Press, Dundalk, 1931. Price 7*s*. 6*d*. net.)

THE book contains a number of wood-block illustrations, the work of the authoress and her sister, and its purpose is well set forth in the short introduction. " This volume is really only an elaboration of the brief notes that have accumulated in connection with these sketches, and our excuse for offering them in this form is that we have a fairly comprehensive collection of authentic pictures which, though they may be too small and slight to be completely satisfactory to a serious student of the subject, yet give a general idea of the type represented, and serve to identify portraits, etc., to the originals of which the reader can in many cases be referred." To leave the matter at that, however, would be doing less than justice to Miss Gardner's delightful book. The notes have been chosen from a wide field with considerable skill and they shed fascinating side-lights on the known and probable history of this most famous type of hound, from ancient times to the present day. The concluding chapter deals with the Irish Wolfhound as we now know it. The authoress has run down her information to its original sources, a procedure that gives the work considerable value and one that might be followed by other writers with advantage. While not a scientific

treatise in the narrow sense of the word, it contains information, including measurements and pedigrees of champion hounds and an account of how the modern stock has been built up, which is of interest to the geneticist. To all concerned with dogs, whether professionally or otherwise, this book will furnish most enjoyable reading, and we should like to congratulate Miss Gardner upon the production of a work so delightful alike in its matter and its form.

C. H. O'D.

The Biology of the Amphibia. By G. KINGSLEY NOBLE, Ph.D. [Pp. xiii + 577, with 174 figures.] (London: McGraw-Hill Publishing Co., 1931. Price 30s. net.)

DR. G. KINGSLEY NOBLE, Curator of Herpetology and Experimental Biology at the American Museum of Natural History, who has himself published a large mass of facts relating to the Amphibia, and who is an expert on the subject, in writing this useful work has done a great service to all those interested in these peculiarly fascinating animals. As he truly says, there is no book written in English since Gadow's volume in the Cambridge Natural History, published in 1901, which attempts to combine both the natural history and the biology of the Amphibia in a single volume.

This is a textbook primarily written for students, but it will interest all naturalists, being clearly written in simple language, and embracing much that is real field work, besides explaining to a certain extent the more modern experimental work of the laboratory. Amphibia are so much used nowadays in experimental biology that it is a specially appropriate time to produce a book of this kind. The full bibliographies at the end of each chapter help much in supplementing the accounts of the more particular subjects where details must of necessity be avoided, especially in the physiological sections.

Part I, the larger portion, treats of the Structure and Function of the Amphibia, Part II treats of their Relationships and Classification.

Not only are recent forms described, but there are many references to ancestral forms, and the probable origin of all the groups are discussed with their relation to one another and to their environment. Of recent Amphibia there are 234 genera and about 1,900 species.

Dr. Noble has several times previously emphasised the importance of the life-histories and the modifications of eggs and larvæ. He shows this again in his chapter on the Mode of Life-History, where the descriptions of the varied methods of egg-laying and incubation are vividly described.

An enormous amount of information is contained in this one volume, and the wealth of delightful illustrations in the text, most of which are original, adds much to its value.

M. V. L.

Insect Pests of Farm, Garden, and Orchard. By E. DWIGHT SANDERSON, Ph.D. Third edition revised and enlarged by L. M. PEAIRS, Ph.D. [Pp. vii + 568, with 607 figures.] (London: Chapman & Hall, 1931. Price 31s. net.)

THIS large volume is essentially a list of the arthropod pests of cultivated crops in the United States. The subject-matter is primarily divided according to the type of crop, the chapters dealing with pests of cereals and grasses, fruits, vegetables, etc. The pests of each main crop are enumerated with a reasonably complete account of the life-history, the nature of the damage, and control-measures. The more important pests are dealt with in considerable detail with useful charts of the life-history in the field. Nearly all the species mentioned, and often also their developmental stages, are illustrated with black and white figures. Most of these are taken from the publications of the U.S. Department of Agriculture. Many of them are distinctly good, and a

number of original photographs are also excellent. The maps showing the range in the U.S.A. are also useful.

In the somewhat limited field they have delimited the authors are to be congratulated on a thorough and painstaking exposition of our existing knowledge. But it is probable that many entomologists would have had a still higher opinion of the work if there had been a greater infiltration of the modern outlook in Economic Entomology. There is little trace in the present volume of the ecological approach to the problems of pest-control. It has been increasingly realised that the empirical methods of the pioneers can never be more than palliative, and have often already given results which cannot be bettered without more research into underlying principles. In recent years there have been numerous attempts at placing our knowledge of the causes of insect outbreaks on a sounder basis. Information as to the normal life-history in the field does not alone suffice; we require also to know the effect on the insect of the variable climatic and biotic factors. Admittedly it is still difficult to summarise present-day knowledge in this growing field, but, at least with some of the more important pests, certain guiding principles are already established. Thus, the application of the developmental unit idea to life-histories under different climatic conditions or the use of climographs in predicting insect-outbreaks would seem worthy of mention. The descriptions of spraying methods may seem more practical, but the authors' estimate of the annual loss due to insects in the U.S.A. ($2,000 million) does not suggest that practice has yet made perfect. To the damage caused by the insects must be added the cost of the existing methods of control, the real effect of which it is usually very difficult to assess.

It appears that in the U.S.A. the pests of cultivated crops number about 322, of which no less than 93 are imported, mostly from Europe. The authors estimate that amongst the really serious pests nearly three-quarters have been introduced by man. The process still continues, and one of the worst pests, *Popillia japonica* (from Japan), did not find a footing till 1916. It is an obvious consequence that the most important problems in Economic Entomology are of more than national importance.

The production of the volume is, generally speaking, good. There is an adequate index, which would be improved by including the names of authors mentioned in the text. No bibliography is provided, but the more important references are given under each species. Only one definite error has been noticed. The life-history of the Pea-Weevil, *Mylabris pisorum*, should be revised. It is now known that the adults hibernate in the fields, so that fumigation of harvested seed has almost no value in control.

O. W. R.

The Insect Menace. By L. O. Howard. [Pp. xv + 347, with 32 plates and many text-figures.] (New York: The Century Co.; London; D. Appleton & Co., 1931. Price 3 dollars 50 cents in New York, 12*s.* 6*d.* in London.)

Dr. L. O. Howard retired from the position of Chief of the U.S. Bureau of Entomology in October 1927, but was retained in the bureau for a further four years until June 1931, when his final retirement closed his fifty-three years' official connection with the department. During these last four years he has prepared two books, *A History of Applied Entomology* (reviewed in the January number) and *The Insect Menace.*

This book is written in a popular manner, being an attempt "to epitomise in a small volume what should be known by everyone. . . . It is intended for the thoughtful general public," to quote the writer's own words. "The object is to arouse such a public to an appreciation of a very real menace to humanity."

In the first chapter—"How long have Insects existed on the Earth?"—it

is shown that insects have had 12,500 times the chance that man has had to evolve a persistent type. This potent opportunity for survival having been emphasised, we pass on to an examination of the reasons why the insect type has persisted. The powers of concealment and of enormous multiplication, the number of species, the anatomical advantages, and the diet and its adaptations are all discussed. In addition, mention is made of the physiology, senses, underground life, and the adaptation to water and to strong winds.

It is then pointed out that the present age of the world, termed Kainozoic, which is often interpreted as the age of man, could quite justifiably be called the age of insects. Man, although nominally supreme on earth, has been creating conditions peculiarly favourable to his greatest rival and, furthermore, he has been taking a long time to appreciate this fact. The problem confronting humanity is laid bare before the reader in a dramatic way. Not content with showing how much food insects are unwittingly encouraged to destroy and how large a bill will have to be met if this is allowed to continue, Dr. Howard next reveals the manner in which insects act as carriers of diseases of man and of plants. But he goes on to state there are beneficial insects or black-legs in the struggle for supremacy.

The world, which for long has glanced rather askance at entomologists, is, however, waking up. Chapters VII and VIII deal with insect control by other insects, variation in crop practice, mechanical and chemical control, and quarantines against insects.

In the final chapter (IX) instances of progress made with regard to three insects are given—namely, the Rocky Mountain locust, the cotton boll-weevil, and the Mediterranean fruit-fly. It is mentioned in the conclusions that prophets of evil have been telling us until recently that human over-population of the world is approaching and birth-control must be adopted or, a more recent suggestion, that scientists have now supplied the means of growing sufficient food. Dr. Howard's own views apparently can be summed up in the two old sayings: "Waste not, want not," and "Prevention is better than cure." He seems to say: stop all waste, cease to pay enormous tribute annually to insects in the shape of food; secondly, avoid spending money in trying to find cures, rather divert as many moneys as possible to the study of fundamentals, such as ecology and insect epidemics.

This book is a thrilling authoritative account of the war between man and insects and seems to carry us right beyond our own flattering man-made idea of the supremacy of man on earth. It should certainly appeal to many. It is well written and has good illustrations. But surely a sufficiently terrifying insect could have been found to replace the spider stamped on the front cover (and also the paper cover)!

H. F. B.

The Biology of Spiders, with Especial Reference to the Danish Fauna. By E. Nielsen. [Vol. I, pp. 248, with 10 figures and 32 plates; Vol. II, pp. 723, with 462 figures, and 5 coloured plates.] (Copenhagen: Levin & Munksgaard, 1932. Price 30s. net.)

Books on spiders are almost as scarce as spiders are numerous. One can recall to memory Blackwell's *History of the Spiders of Great Britain* (1861–4) (very rare), Comstock's *Spider-book* (1912), Ellis's *Spiderland* (1912), McCook's *American Spiders and their Spinning Work*, I–III (1889–93), Pickard-Cambridge's *Spiders of Dorset* (1879–81), Savory's *British Spiders* (1926), and his *Biology of Spiders* (1928), Simon's *Arachnides de France*, I–VII (1874–1926), and his *Histoire Naturelle des Araignées*, I–II (1892–7), Staveley's *British Spiders* (1866), and Warburton's article on "Spiders" in the *Cambridge Natural History* (1909), and his *Spiders* (1912). Naturally there are many valuable papers scattered through the literature, but these are less accessible to the beginner. It is therefore pleasing to see the appearance of Nielsen's *Biology of Spiders*.

This book is published in an unusual style. Vol. I is written in English, and is an abbreviated translation of the subject-matter contained in Vol.II. However, no reference nor précis is given of section 1 of vol. II, which deals with the Morphology and Anatomy. There is also a supplement to the catalogue of Danish spiders which is contained in vol. II, in addition to which there is a translation of all the legends of the illustrations in vol. II and an index of Families, Genera, and Species.

Vol. II is written in Danish, and contains more subject-matter than vol. I. There are five sections, dealing respectively with the Morphology and Anatomy, General Biology, Four-lunged Spiders, Genuine Spiders, and the Parasites of Spiders. Then is given a catalogue of Danish Spiders by J. Braendegaard, and a bibliography of books and papers available to workers in Denmark. Finally, there is an index, five coloured plates and their explanations, and a list of corrigenda.

By this mode of publication English readers can obtain the essentials of the subject-matter and explanations of the illustrations from vol. I while using vol. II as a book of illustrations and references. The lists of Danish spiders and their parasites are also accessible in this volume. We consider that the author has achieved his object of making his book available to the English-speaking races.

Whereas only about sixty-five pages are devoted to morphology and anatomy, the great bulk of the work consists of detailed observations of the best natural-history type. This is particularly characteristic of vol. II, which is written in most picturesque language. The amount of information is stupendous and the quality good. The figures, of which a large proportion are from photographs, and the plates are especially noteworthy. The only criticism necessary is that the volumes are too bulky for paper covers, and will have to be bound to prevent them falling to bits under constant handling. But the paper covers are no doubt partly responsible for the moderate price (30*s*.). We should like to recommend this book to all those interested in spiders.

H. F. B.

Animal Ecology, with Especial Reference to Insects. By ROYAL N. CHAPMAN. [Pp. x + 464, with 137 figures and 27 tables.] (London : McGraw-Hill Publishing Co., 1931. Price 24*s*. net.)

As far back as 1917, in the infancy of animal ecology, a course in Insect Ecology was being given at the University of Minnesota. In 1926 the lecture notes were published in mimeographed form, and thus became available in their latest aspect to those who were not fortunate enough to be able to listen to Prof. Chapman himself. The demand for the volume can be gauged by the fact that a second edition appeared in 1927. Since then animal ecology has assumed far greater importance, and animal ecologists even have their own journal, as witness the advent of the *Journal of Animal Ecology*, published for the British Ecological Society. The older descriptive and natural history type of animal ecology, as exemplified by Pearse's *Animal Ecology* (McGraw-Hill Book Company, 1926), has now resumed its proper proportion in ecology, and is no longer overshadowing the other branches of the science. We consider it unfortunate that the same title has been used for the books of both Pearse and Chapman.

In the present book Prof. Chapman has published his course of lectures in printed form, and has brought the subject-matter up to date to 1930. Nevertheless, in a science that is progressing so rapidly, such a work must be slightly out of date so soon as it is published. For example, it has not been possible to mention Uvarov's *Insect and Climate* (April 1931).

It is convenient to divide the book into two divisions, the first dealing with autecology, which is " interpreted as including the study of the various

factors of the environment in relation to insects and other animals," and the second dealing with synecology, which is "considered as population systems on the basis of biotic potential and environmental resistance, and as distributional and descriptive ecology."

In the section on autecology, there are chapters on light, temperature, and moisture as ecological factors, and in addition a chapter on the effects of temperature and moisture acting together in the ecology of animals, including an appendix on dormancy. Next follow chapters on the physical conditions of environmental media, nutrition, and biotic factors in autecology.

In the section on synecology, after a preliminary discussion of the subject, there are chapters on chorology (zoogeography) and chronology. Then aquatic synecology, the physical and biotic characteristics of aquatic communities, lenitic environments, lakes, and lotic environments receive attention. Next, terrestrial synecology is dealt with in chapters on communities of the soil, sand dune, grass or herb stratum, shrub and tree strata. In this last chapter there is a section on applied ecology.

Throughout at the end of each chapter there is a bibliography, a very useful mode of reference. But in the index at the end of the book it is not possible to find what works have been mentioned, or should be read, by simply referring to the authors' names. The index is an index to the subject-matter, not to the bibliography.

The Appendix consists of a translation of a paper, by Prof. Vito Volterra, on variations and fluctuations of the number of individuals in animal species living together, which appeared in the *Journal du Conseil international pour l'exploration de la mer*, III, vol. I, 1928. In this way a valuable contribution is made accessible to a wider public.

Prof. Chapman's book is a real textbook, and is absolutely indispensable to all students of ecology, and might be read with advantage by all biologists. Naturally, in such a comprehensive survey of so wide a subject, there are a few minor mistakes that have been overlooked. For example, there is no explanation of what the axes of the graph represent in Fig. 5 on p. 18; on pp. 6 and 73 the same book by Adams is referred to as having 149 pp. and 183 pp.; and in the index on p. 452 Maldwyn Davies is spelt Maldwin. But these are almost inevitable in a first edition, and, if they are pointed out, a second edition will remedy the fault.

The book is characterised by the clearness of exposition, the thoroughness with which each subject is outlined, the ample lists of references by means of which one can pursue any line of special interest, and the comparative cheapness of the volume. Royal N. Chapman is to be congratulated and thanked.

H. F. B.

Textbook of Experimental Cytology. By J. GRAY. [Pp. x + 516, with 3 plates and 202 text-figures.] (Cambridge: at the University Press, 1931. Price 25*s*.)

THIS book, dealing as it does with the "experimental" approach to the problems of cytology, attacks the subject from a very different angle than that of classical cytomorphologists. The method of approach adopted by the author is analytical, as distinct from inductive. It is concerned chiefly with recent experimental research on cell physiology, and the present state of our knowledge of the physical structure and biological properties of the living cell.

During the earlier part of the present century morphological cytology yielded results of immense importance, and the stimulus which the subject received in consequence attracted many research workers, and gave rise to a rapidly increasing annual volume of publications dealing with descriptive
This result was due, in the first place, to the contact established

by the Mendelian theory between nuclear cytology and the study of heredity. Out of this contact modern genetics has grown. Subsequently, the discovery of such cytoplasmic structures as the mitochondria and Golgi bodies provided another impetus. In more recent years the opinion appears to have been growing among biologists that descriptive cytology has almost attained, for the time being, the limits of its usefulness, and that further advances must be looked for in other fields, such as genetics and experimental physiology. Those who participate with the reviewer in this temporary dissatisfaction with the methods of classical cytology will find in the present book an able introduction to an aspect of the subject which is young and virile, and which has already yielded results of fundamental significance.

The book covers a wide field, chapters being devoted to cell dynamics, mitosis, cell division, variability, growth, as well as to the physical properties of protoplasm and of the various parts of the cell. Germ-cells, contractile cells, and phagocytosis are also dealt with separately. The author has imparted a remarkable degree of coherence to his subject-matter, despite the wide field which it covers and the variety of sources from which it is drawn. The presentation is clear, concise, and sufficiently simple to be readily readable by those who have only a limited knowledge of physics and chemistry. The treatment is critical, but the criticism is both careful and impartial. Care is taken throughout to emphasise the points on which knowledge is most inadequate, and on which further research is likely to yield important results. Useful bibliographies are appended to each chapter, and the quality of the illustrations is good. No book, however perfect, is beyond criticism for those who seek to criticise, and a book on experimental cytology is open to the combined criticism of the physicist, the chemist, and the biologist. We prefer to recommend it, without reservation, as an excellent introduction, for the student or research worker, to "experimental" cytology, and to compliment the author on a difficult achievement. It is one of the most stimulating contributions to biological literature which has appeared during recent years.

F. W. R. B.

A Theory of the Formation of Animals. By W. T. Hillier, M.R.C.S., L.R.C.P. [Pp. viii + 166, with 98 figures and 7 plates.] (Bristol: John Wright & Sons; London: Simpkin & Marshall, 1932. Price 8*s*. 6*d*. net.)

Mr. Hillier disarms our criticism at the outset: "The absence of a bibliography and the entire disregard of contemporary views have no more significance than that they indicate the inability of the writer to deal with such matters." His guiding principle, he tells us, is: "Be as imaginative as you please, but control your deductions by facts in Nature observed as accurately as possible." He has certainly carried out, at any rate, the first part of his motto.

It is necessary, the author tells us, to be dogmatic in order to be clear; but unfortunately a dogmatic style does not invariably result in lucidity. He takes as his text Oken's idea that every animal consists of two individuals rolled into one—the "dual constitution" theory. He sees evidence in support of this in such divers subjects as metamerism, disinfection, fertilisation, the gastrula, and spiral cleavage—though he does not always make it clear why they support the theory. In the development of Polygordius he sees evidence of ancestry by the fusion of separate individuals while still in the blastula stage, in a manner which he compares with pædogenesis in Axolotl. He describes the evolutions of four such ancestral blastulæ, which he believes co-operate in the ontogeny. The further activities of these "phantom blastulæ," as he calls them, lapse into metaphysical geometry which we are not competent to criticise.

He devotes a long chapter to a detailed account of the anatomy of the herring, little of which has any connection with his theory. He is a thoroughgoing iconoclast, and coolly announces that though it may be entirely out of line with present-day opinion, he proposes to treat the tail of fish as serially homologous with the paired fins; though he gives practically no evidence in support. On the strength of observations on herring alone, he casts doubt on the existence in mammalian bone of canaliculi putting the lacunæ in communication. He postulates the existence of a set of special channels for the dehydration of bones. He assumes that these imaginary channels may undergo great changes in the course of development, and so the form of a bone which is controlled by them may vary widely. Hence, by postulating sufficiently great changes, any bone may be homologised with almost any other bone. He describes this as a process of "free translation"; many zoologists would prefer a less charitable description. Proceeding on these lines, he arranges the bones of the herring in a series of groups which appear to have for believers some mystic significance, like the biblical number seven. His magic number is nine, and with the aid of some jugglery he produces several groups of nine or a multiple of nine in various metameric structures —notably fin-rays and vertebræ; each group apparently representing an ancestor, and all the ancestors having equal powers of asexual growth, characterised by the serial repetition of similar parts

Altogether a book which, as the author naïvely admits, proceeds "more by argument than from the solid foundation of well-ascertained fact."

L. H. J.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Elementary Trigonometry. By John Prescott, M.A., D.Sc., and H. V. Lowry, M.A. London: Longmans, Green & Co., 1932. (Pp. xi + 444.) Price 5*s*. net.

Foundations of the Theory of Algebraic Numbers. By Harris Hancock, Ph.D. (Berlin), Dr.Sc. (Paris), Professor of Mathematics in the University of Cincinnati. Vol. I. Introduction to the General Theory. New York: The Macmillan Company, 1931. (Pp. xxvii + 602.) Price $8.00.

An Introduction to the Theory of Canonical Matrices. By H. W. Turnbull, M.A., F.R.S., Regius Professor of Mathematics in the United College, University of St. Andrews, and A. C. Aitken, D.Sc., Lecturer on Statistics and Actuarial Mathematics in the University of Edinburgh. London and Glasgow: Blackie & Son, 1932. (Pp. xiii + 192.) Price 17*s*. 6*d*. net.

A Textbook of Practical Astronomy Primarily for Engineering Students. By Jason John Nassau, Professor of Astronomy, Case School of Applied Science. London: McGraw-Hill Publishing Co., Aldwych House, W.C.2, 1932. (Pp. x + 226.) Price 18*s*. net.

Sydney University Reprints. Series XI. Physics, Mathematics, and Astronomy. Vol. I. Nos. 20–25.

Vision and Colour Vision. By R. A. Houstoun, M.A., D.Sc., Lecturer on Physical Optics in the University of Glasgow. London: Longmans, Green & Co., 1932. (Pp. vii + 238, with 102 figures.) Price 5*s*. net.

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The Biological Concept of Man A Brief Introduction. By A. H. Miller, M.D. Camb., M.R.C.P. Lond. Bournemouth: Bournemouth Guardian Ltd., 158 Commercial Road, 1932. (Pp. 13.) Price 1s. 6d. net.

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SCIENCE PROGRESS

RECENT ADVANCES IN SCIENCE

APPLIED MATHEMATICS. By Prof. F. E. RELTON, D.Sc., M.A., Royal School of Engineering, Giza.

IN my last article I surveyed the work that has recently appeared in journals more immediately accessible to English-speaking readers. I shall utilise the present opportunity for the survey of a somewhat wider field.

Mechanics.—Among the papers that correlate theoretical mechanics with the geometry of space, there is one by G. Vitali, "Alcuni elementi di Meccanica negli spazi curvi," *Ann. Mat. pura ed. appl.*, vol. IV, **9**, 75–89 (1931). The first and theoretical section develops the idea of a vector in n-dimensional space and its laws of transformation; the motion of a point and its velocity; fields of force, and the behaviour of material particles therein. Each material particle is endowed with a twofold mass, respectively called *massa inerte* and *massa attiva*. The second and applied section deals first with the case of central motion in three-dimensional space under the inverse square law. This three-dimensional space is then taken to be spherical and immersed in a four-dimensional manifold, and the motion is again considered for a central force obeying the Newtonian law. Equations analogous to the usual equations of motion are derived, but they are equally incapable of giving a perihelion motion, though the author expresses the opinion that this might be overcome by a change in the law of attraction. The treatment possesses elegance and simplicity, and the methods and underlying ideas are a development of those expounded in the author's book, *Geometria nello spazio Hilbertiano* (Bologna, 1930).

For those who are not afraid of eits, eifs (as Bateman calls them), integral invariants, and groups of automorphisms, a short paper by B. O. Koopman, "Hamiltonian Systems and Transformations in Hilbert Space," *Proc. Nat. Acad. Sci. U.S.A.*, **17**, 315–8 (1931), may be of interest, especially as the author does not exhaust the subject, and suggests further extensions of the theory. In his last article in this quarterly

G. J. Temple emphasises the importance of Koopman's work in its application to statistical mechanics. Contact transformations and Lie's theory are prominent in a short paper by E. Schuntner: "On the Equivalence and Classification of Dynamical Problems," *Ann. Mat. pura ed. appl.*, IV, 9.

A full understanding of the problem of impact requires considerations of elasticity, and a knowledge of the work of Hertz and his successors is indispensable. The simpler treatment that suffices in mechanics dates back to the time of Wallis and Wren. The classical paper on inelastic collisions is Appell's memoir of 1896, *J. de Math.*, 5, 11, in which he gives, with wide generality, a theory applicable to dynamical systems. The geometrico-dynamical ideas of J. L. Synge (*Phil. Trans. Roy. Soc.*, A 226, 1926) continue to exert a marked influence, and something analogous to them has been adopted for a general discussion of impact by Z. Horák: "Théorie générale du choc dans les systèmes matériels," *J. Ecole Polytech. Paris*, II, H 28, 15–64 (1931). The author considers Riemannian space with a metric in which the components of the fundamental tensor are proportional to the corresponding terms in the kinetic energy. The calculation of the covariant differentials of the momentum vector, with the usual Christoffel 3-index symbols, enables him to write the equations of motion as if for a single particle. The analogue of the coefficient of restitution is introduced as an affinor of restitution. General theorems on impact are derived, and in the latter part of the paper particular problems are discussed, including two smooth bodies and also two perfectly rough bodies.

The question of impact, under a different aspect, is of some account in the problem of three bodies. It was Painlevé, in his work on the analytic theory of differential equations, who first showed that the co-ordinates are holomorphic functions of the time, provided the initial conditions are such as to obviate a collision taking place after a finite interval. The situation was improved in 1912, when K. F. Sundman showed that an impact of two of the bodies did not give rise to an essential singularity, and that the singularity which arose could be removed by suitable changes of variables. Sundman's work was mathematically unexceptionable, but the resulting convergent series were of doubtful worth for practical purposes. This aspect has been discussed by D. Belorizky: "Sur la convergence des séries dans la solution du problème des trois corps donnée par M. Sundman," *C. r. Acad. Sci. Paris*, 193, 314–7 (1931). The author discusses three cases, in which the ratio of the total mass to the mass of the smallest body is 200, 10, and 3 respectively, the masses being situated at the corners of an equilateral triangle. If the author's work is correct, the number of terms

required for even rough accuracy is, to say the least of it, depressing.

The derivation of dynamical equations from a variational principal with certain restrictions has been the subject-matter of several recent investigations. P. S. Bauer, in a very short paper, " Dissipative Dynamical Systems," I, *Proc. Nat. Acad. Sci. U.S.A.*, **17**, 31–4 (1931), investigates the nature of the coefficients when certain dynamical equations are the Eulerian equations for minimising an integral. Incidentally the same journal, pp. 370–6, contains a geometrico-dynamical paper by E. Kasner, " Dynamical Trajectories and the ∞^3 Plane Sections of a Surface." Bauer's paper might be read in conjunction with one by A. Wundheiler, " Über die Variationsgleichungen für affine geodätische Linien und nichtholonome, nichtconservative dynamische Systeme," *Prace Mat.-fiz.* **38**, 129–46 (1931). The last-mentioned journal, pp. 1–20, contains a paper by M. Kerner : " Le Principe de Hamilton et l'holonomisme." Personally I have never felt really satisfied with the usual application of Hamilton's principle to non-holonomous systems ; there is too much air of *tant pis pour les faits* and making the principle a Procrustean bed. Those who read Kerner's paper will, of course, first familiarise themselves with the relevant work of Hölder and Voss.

The theory of the oscillations of a dynamical system does not usually present much difficulty, especially as the applied mathematician is generally prepared to take for granted certain necessary propositions in pure mathematics. Faced with the necessity of actually computing the periods for systems with eight or ten degrees of freedom, he is inclined to give a curt nod to statements about Elementartheiler. The computational work entailed by complicated systems can be very tedious. An examination of the problem, with the computer's needs in view, has appeared (unfortunately in Russian) in a paper by A. Krylov, " On the Numerical Solution of the Equation Determining the Frequencies of Small Oscillations," *Izv. Akad. Nauk. U.S.S.R., Otdel. mat. i. estest. Nauk.*, VII, **4**, 491–539 (1931). The author evolves a method of reaching the final determinantal equation in a form that has the parameter in the first column only. Usually it appears in every term, and in the case of normal co-ordinates, down the leading diagonal only. The determinant is now much easier to develop ; the paper contains an extension to include gyroscopic terms, and there are numerical examples with schemes for calculation.

Hydrodynamics.—Many papers of recent date deal with the viscous liquid. Among the more interesting we may first notice one by F. Sbrana, " Sui moti di un fluido incomprimibile, simmetrici rispetto ad un asse," *Atti Soc. Ligust. Sci.*, **10**,

63–86 (1931). Vectors are used in conjunction with cylindrical co-ordinates, and the symmetry about the axis enables the velocity, vorticity, and pressure to be expressed in terms of two functions, together with the kinematical viscosity. Attention is devoted to the consequences of endowing an immersed solid with helicoidal motion, particularly when the solid is spherical. Mention must also be made of A. Foch and J. Bariol, " Sur le mouvement d'un fluide visqueux au voisinage d'un disque oscillant autour de son axe," *C. r. Acad. Sci. Paris*, **192**, 835–6 (1931).

S. Higuchi has a note on the oscillatory motion of a viscous liquid in an open channel of infinite length, *Tech. Rep. Tohoku Univ.*, **9**, 665–9 (1931). Oscillations are generated in the liquid by the vibration of the boundary. The channel is of semi-circular section, and a table shows the rapidity with which the wave decays with distance from the boundary. J. Leray writes : " Sur le système d'équations aux dérivées partielles qui régit l'écoulement permanent des fluides visqueux," *C. r. Acad. Sci. Paris*, **192**, 1180–2 (1931). This is suited only to those who are pretty well versed in the modern outlook on partial differential equations ; it would probably be of as much interest to the analyst as to the applied mathematician. Similar remarks probably apply to the work of G. Lampariello, " Sull'impossibilità di propagazioni ondose nei fluidi viscosi," *Atti Accad. naz. Lincei*, VI, **13**, 680–91 (1931), wherein Duhem's theorem, that true wave propagation cannot take place in a compressible viscous fluid, is given a simple and direct proof by the theory of characteristics.

J. Kampé de Fériet writes : " Sur une classe de mouvements plans d'un fluide visqueux incompressible," *Ann. Soc. Sci. Brux.*, A **51**, 7–11 (1931). The author develops a method of finding a certain class of exact integrals for the equations of non-steady plane motion for a viscous, incompressible fluid. The necessary and sufficient conditions that an assumed velocity distribution should be possible are proved to consist in a certain function satisfying a partial differential equation of parabolic type. Cases arise in which this equation transforms into the equation for heat-conduction, so that all the known integrals of the latter lead to possible motions.

Stability is discussed by W. T. MacCreadie, " On the Stability of the Motion of a Viscous Fluid," *Proc. Nat. Acad. Sci. U.S.A.*, **17**, 381–8 (1931). The flow is two-dimensional between parallel planes. Simple expressions are taken for the fluctuations of the velocity components, and the process of minimising the integral that represents the Reynold's number is a double one. It is first approached from above by something analogous to Ritz's method, and is afterwards approached from below in

a different manner. Numerical results permit comparison with established values. At the same time we have A. Rosenblatt, "Sur la stabilité des mouvements laminaires des liquides visqueux incompressibles," *C. r. Acad. Sci. Paris*, **193**, 220–2 (1931), wherein the two boundary planes move with equal and opposite velocities. A paper from the same pen and bearing the same title appeared in *Atti Accad. naz. Lincei*, VI, **14**, 93–9 (1931). Other short papers by the same author are: "Sur certains mouvements stationnaires des fluides visqueux incompressibles," *Proc. Third Inter. Cong. Tech. Mech. (Stockholm)*, vol. I, 351–4; "Sur les mouvements plans des liquides visqueux voisins des mouvements radiaux," *C. r. Acad. Sci. Paris*, **192**, 920–2 (1931); "Sur les mouvements des liquides visqueux symmetriques par rapport à un axe," *C. r. Acad. Sci. Paris*, **193**, 139–41 (1931); "Sur certains mouvements plans des liquides visqueux," *Bull. Sci. Math.*, II, **55**, 175–92 (1931), this last completing some work of Hamel's on radial flow.

In the realm of the perfect fluid, the most interesting of recent work lies in two related papers by U. Cisotti. In the first of these, entitled, "Correnti circolatorie locali intorno a regioni di acqua morta," *Atti Accad. naz. Lincei*, VI, **13**, 85–92 (1931), the author utilises a method, devised by himself and Levi-Civita, for treating the circulation round a dead-water region. Use is made of the transformation $z = i(\varsigma^2 - 2i\varsigma + 1)/(\varsigma^2 + 2i\varsigma + 1)$, whereby the semicircle $(-1, i, 1)$ of the ς-plane is conformally represented on the part of the z-plane external to $|z| = 1$. With a vortex at $z = 0$ we have the complex potential $2\pi i f = C \log z$, there being a corresponding form for the ς-plane with a vortex at $\varsigma = i(\sqrt{2} - 1)$. The velocity is then given by $df/d\varsigma$. Two cases are considered; if the dead-water region has a free boundary, it is shown to be necessarily circular; if the boundary is in part free and partly fixed, the analysis becomes more difficult. The paper concludes with an electrical interpretation of the results. The sequel, occupying pp. 247–53 of the same journal, is entitled "Circolazioni intorno a regioni di acqua morta limitate da una parete poligonale e da un pelo libro." It comprises two special cases of the second part of its predecessor. The analysis is first worked out for the case of a straight boundary and an electrical interpretation is given. In the second case, the boundary is taken as a straight-sided polygon; in particular, two lines of equal length.

Elasticity.—Most of the interesting and recent papers on this subject have either already been noticed, or will be found collected in the *Proceedings of the Third International Congress*, held at Stockholm. We may add a paper by T. Boggio, "Sull'operatore di Laplace e sulla equazioni dell'elasticità

negli spazi curvi," *Atti Accad. naz. Lincei*, VI, **13**, pp. 412–16 (1931). The notation used is that of the *Geometria Differenziale*, by Burgatti, Boggio, and Burali-Forte. The methods employed were expounded in a previous paper, *Rendiconti dei Lincei*, VI, **7**, pp. 811–17 (1928). The paper is a generalisation of the differential vector relation $\nabla_\wedge \nabla_\wedge u = \nabla\nabla \cdot u - \nabla^2 u$. Applications are made to space of constant curvature and to the equilibrium equations for an isotropic elastic medium in three-dimensional space. A somewhat allied paper, though not specifically concerned with elasticity, is by H. S. Ruse: "Generalised Solutions of Laplace's Equation," *Proc. Edin. Math. Soc.*, II, **2**, 181–8 (1931), wherein solutions are obtained of the general potential equation

$$g^{\lambda\mu}\left\{\frac{\partial^2 V}{\partial x^\lambda \partial x^\mu} - \Gamma^{\ \ \alpha}_{\lambda\mu}\frac{\partial V}{\partial x^\alpha}\right\} = 0$$

in n-dimensional space with a metric $ds^2 = g_{\mu\nu}\, dx^\mu\, dx^\nu$.

Wave propagation is treated by G. Lampariello, "Propagazione di onde nei mezzi elastici isotropi anche non omogenei," *Atti Accad. naz. Lincei*, VI, **13**, 856–60 (1931). The paper is quite short, and its nature is sufficiently indicated by its title.

Those who have to discuss the torsion problem for awkwardly shaped cross-sections will be familiar with the work of F. Kötter (1908) on the L-section. The applicability of his method is limited to sections with one re-entrant angle. There is also the work of E. Trefftz (1912), with its partially graphical method. We are now confronted with a paper by I. S. Sokolnikoff, "On a Solution of Laplace's Equation, with an Application to the Torsion Problem for a Polygon with Re-entrant Angles," *Trans. Amer. Math. Soc.*, **33**, 719–32. The method is applicable to all regions conformably representable on the upper half-plane when the boundary becomes the real axis. Naturally the Schwarz-Christoffel transformation is employed; application is made to the T-section.

It would be interesting to know what proportion of research workers in elasticity have had a quiet nibble at the problem of a sphere compressed between two flat plates, or something similar connected with hardness tests. One, more daring than the rest, has published his results—B. Sen, "On the Stresses in an Elastic Sphere having certain Discontinuous Distributions of Normal Pressures on the Surface," *Bull. Calcutta Math. Soc.*, **23**, 67–76 (1931). With no desire to condemn the paper before closer study, it is safe to say that its analysis should be accepted only after the most critical inspection, a remark which applies to any work based on divergent series.

I would draw attention to a long and interesting paper by

W. Meyer zur Capellen, "Methode zur angenäherten Lösung von Eigenwert problemen mit Anwendung auf Schwingungsprobleme," *Ann. Physik*, V, F. 8, 297–352 (1931). Perturbation theory methods are directed to the approximate solution of applied oscillation problems. The examples considered are: (i) longitudinal vibrations of a rod with variable cross-section; (ii) vertical oscillations of a chain hanging from two points with deep sag; (iii) transverse oscillations of a freely hanging chain; (iv) vibrations, due to bending, of a beam with variable cross-section. The approximations obtained by numerical and graphical methods are compared with the corresponding experimental results.

The American *Mathematical Monthly* states that no fewer than forty new periodicals of confessedly mathematical complexion have made their appearance in the world since 1926. Twenty-three of these may be definitely classed as "research." The *place d'honneur* falls to Roumania with seven; there is food for reflection in the fact that England ties with Czechoslovakia, at the bottom of the list, with one.

MATHEMATICAL PHYSICS. By Prof. G. Temple, Ph.D., D.Sc., King's College, University of London.

This article is a summary of the work on quantum theory which has been developed by Eddington during the last few years. These researches lie in the hitherto unknown sea between relativity theory and quantum theory, a sea which is now being explored with the help of Dirac's linear wave equation as a kind of mariner's compass. The final object of Eddington's work, if I understand it aright, is to exhibit the theory of relativity in its metrical and dynamical aspects as a natural development of the quantum theory. The method employed is to accept Dirac's linear wave equation as the appropriate quantum characterisation of an elementary particle, and to explore, in a tentative and semi-empirical manner, the significance and implications of this equation.

The results obtained to date may be conveniently divided into two classes—the first comprising the general properties of spin operators and wave tensors, and the general form for the interaction of electric changes; while the second class of results consists of the values of certain natural constants—the charge on an electron, the cosmical constant, and the ratio of the masses of the proton and the electron. At the present time physicists are, perhaps, inclined to regard the second class of results as more speculative in character and their method of inference as more precarious.

Dirac's Linear Wave Equation.—For the sake of making this report complete in itself it will be well to begin with a brief

account of Dirac's linear wave equation. In quantum theory the vector ψ_t, representing the state of a system at time t, is derived from the vector ψ_0 representing the state initially, by a unitary transformation $U(t)$. These transformations form a group with the law of composition,

$$U(t_1)\ U(t_2) = U(t_1 + t_2),$$

whence a particular transformation, $U(t)$, can be expressed in the form,

$$U(t) = exp\left\{-\frac{i}{h}tH\right\}$$

where $i^2 = -1$, and H is in effect the infinitesimal operator of the group $\{U(t)\}$. h is Planck's constant divided by 2π—introduced into the above expression to give H the dimensions of energy and thus justify its name as the Hamiltonian operator. Hence ψ_t satisfies the equation,

$$-\frac{h}{i}\frac{\partial\psi}{\partial t} = H\psi.$$

The form of the operator H is determined by two considerations—the wave equation for ψ must be relativistically invariant and it must be approximately equivalent to the Gordon-Schrödinger relation,

$$H^2/c^2 = p_1^2 + p_2^2 + p_3^2 + m^2c^2,$$

where p_1, p_2, p_3 are the momentum operators and m is the proper (rest) mass of the electron. Therefore, since H is linear in $\partial/\partial t$, it must also be linear in $\partial/\partial x = ip_1/h$, etc. Accordingly it must have the form,

$$H = c(\alpha_1 p_1 + \alpha_2 p_2 + \alpha_3 p_3 + \alpha_4 mc).$$

The second condition then shows that the "spin" operators α_1, α_2, α_3, α_4 must satisfy the equations,

$$\alpha_n^2 = 1,$$
$$\alpha_m\alpha_n + \alpha_n\alpha_m = 0, \quad (m \neq n).$$

The Representation of the Spin Operators.—Dirac [1] and Schouten have shown that the spin operators α_1, α_2, α_3, α_4 can be expressed in terms of two permutable sets of quaternionic operators $(\sigma_1, \sigma_2, \sigma_3)$ and (ρ_1, ρ_2, ρ_3) by writing

$$\sigma_1 = -\iota\alpha_2\alpha_3,\ \sigma_2 = -\iota\alpha_3\alpha_1,\ \sigma_3 = -\iota\alpha_1\alpha_2;$$
$$\rho_1 = -\iota\alpha_1\alpha_2\alpha_3,\ \rho_2 = \alpha_1\alpha_2\alpha_3\alpha_4,\ \rho_3 = \alpha_4.$$

Then $\qquad \sigma_1^2 = 1,\ \rho_1^2 = 1$, etc.,

and $\qquad \sigma_1\sigma_2 = i\sigma_3,\ \rho_1\rho_2 = i\rho_3$, etc.

It follows that the irreducible representations of the spin operators are matrices of *four* rows and columns, which are determined from the matrix representations of the quaternions by the equations,

$$\alpha_1 = \rho_1\sigma_1,\ \alpha_2 = \rho_1\sigma_2,\ \alpha_3 = \rho_1\sigma_3,\ \alpha_4 = \rho_4.$$

All the irreducible representations are equivalent to a particularly simple set of representations, in which all the matrices are "four-point" matrices, *i.e.* matrices such that in any row, or in any column, there is only one non-zero element, and this element is ± 1 or $\pm i$. A geometrical deduction of this result has been given by Zariski (1932). He notes that the four spin operators and their products represent certain collineations in three-dimensional complex projective space. If β and γ are any two products formed from the spin operators, *e.g.* $\alpha_1\alpha_2$ and $\alpha_2\alpha_3\alpha_4$, then (*a*) $\beta^2 = \pm 1$, $\gamma^2 = \pm 1$, and (*b*) $\beta\gamma = \pm \gamma\beta$. These relations imply that the collineations are: (*a*) non-degenerate and involutary, and (*b*) permutable. Hence the spin operators generate an abelian group of involutary collineations of order sixteen. By means of a theorem due to Study it can then be proved that this group is the collineation group of a Kummer configuration. This result yields at once the explicit form of a representation of the group in terms of four-point matrices, first given by Eddington in 1928 [1].

In studying the properties of this group it is convenient to take as a basis four anti-commuting matrices, E_1, E_2, E_3, E_4, which satisfy,

$$E_\mu^2 = -1,\ E_\mu E_\nu = -E_\nu E_\mu,\ (\mu \neq \nu).$$

Let $$E_5 = iE_1E_2E_3E_4.$$

Then $$E_5^2 = -1 \text{ and } E_\mu E_5 = -E_5E_\mu.$$

Finally we write,

$$E_{\mu\nu} = E_\mu E_\nu = -E_\nu E_\mu,\ (\mu, \nu = 1, 2, 3, 4, 5\ ;\ \mu \neq \nu),$$
$$E_\mu = E_{\mu o} = E_{o\mu}.$$

The fifteen matrices $E_{\mu\nu}$ are now all anti-symmetrical in the suffixes μ and ν. They anti-commute (*i.e.* are "perpendicular") or commute according as they have or have not one suffix in common. Not more than five matrices can be mutually perpendicular (Eddington [1]), and all the possible sets of five naturally perpendicular matrices are obtained by fixing one of the two suffixes, *e.g.* E_{30}, E_{31}, E_{32}, E_{34}, E_{35} [1 and 2]. In such a perpendicular set two matrices are wholly real and three are wholly imaginary (Eddington [3], Newman, Zariski). All

fifteen of the matrices $E_{\mu\nu}$ are "skew," *i.e.* if e_{jk} is the element of one of these matrices in the j^{th} row and k^{th} column, then,

$$e_{jk} + e_{kj}{}^* = 0,$$

the asterisk denoting the conjugate complex quantity.

It is also convenient to write $F_1, F_2, \ldots, F_{15}$ for the matrices $E_{\mu\nu}$, now using a single suffix notation, and to put $F_{16} = i$. The set of sixteen matrices, $\{F_\mu\}$, is called a complete set. Two complete sets, $\{F_\mu\}$ and $\{F_\mu'\}$ in one-to-one correspondence, provide equivalent representations of the same abstract group, and are connected by the canonical transformation,

$$F_\mu' = P^\dagger F P,$$

where $$P = \frac{1}{4}\Sigma F_\mu F_\mu', \; P^\dagger = \frac{1}{4}\Sigma F_\mu' F_\mu,$$

and $$P^\dagger P = P P^\dagger = 1.$$

The Transformation Theory.—The components of a mixed tensor, $T_\mu{}^\nu$, can be regarded as the elements of a matrix T with four rows and columns. Any such matrix is a linear function of the sixteen matrices, $\{F_\mu\}$, of a complete set; whence T is expressible in the form

$$T = \Sigma t_\mu F_\mu = \Sigma t_{\mu\nu} E_{\mu\nu},$$

where the t_μ are numerical coefficients called the matrix components of T. The matrix components and the tensor components are connected by the relation,

$$t_\mu = -\frac{1}{4}\chi(TF_\mu),$$

where $\chi(A)$ denotes the characteristic or trace of the matrix A, *i.e.* the sum of its diagonal elements. (In the language of tensors, $\chi(T)$ is the contracted tensor of T, and is therefore an invariant) [1 and 2].

The law of transformation of a mixed tensor, *i.e.*

$$T'_\mu{}^\nu = \sum_{\sigma,\tau} \frac{\partial x'_\nu}{\partial x_\tau} T_\sigma{}^\tau \frac{\partial x_\sigma}{\partial x'_\mu},$$

can be written in matrix form as

$$T' = QTQ^{-1},$$

where Q is the matrix whose μ, ν – element is $\partial x_\nu / \partial x_\mu'$. If

$$Q = \exp\left(\frac{1}{2}E_{\mu\nu}\theta\right) = \cos\frac{1}{2}\theta + \sin\frac{1}{2}\theta \, . \, E_{\mu\nu},$$

eight of the matrix components of T are unchanged (the coefficients of the F's which commute with $E_{\mu\nu}$), and the four remaining pairs are rotated according to the law

$$t_\mu' = t_\mu \cos\theta - t_\nu \sin\theta,$$
$$t_\nu' = t_\mu \sin\theta + t_\nu \cos\theta, \text{ etc.}$$

The set of transformations obtained by taking $\mu, \nu = 1, 2, 3, 4, 5$ ($\mu \neq \nu$) generate a group, under the transformations of which $t_{10}, t_{20}, t_{30}, t_{40}, t_{50}$ behave like a vector in five-dimensional space, while the components $t_{12}, t_{13}, \ldots, t_{45}$ transform as a $10 -$ vector, and $t_{16} = -\frac{1}{4}i\chi(T)$ is an invariant. If we consider the sub-group obtained by suppressing the transformations involving the suffix "5," then the sixteen components $t_{\mu\nu}$ constitute (*a*) two invariants t_{50} and t_{16}; (*b*) two-space vectors $t_{10}, t_{20}, t_{30}, t_{40}$ and $t_{15}, t_{25}, t_{35}, t_{45}$; (*c*) a 6-vector $t_{23}, t_{31}, t_{12}, t_{14}, t_{24}, t_{34}$.

Wave Tensors.—In Dirac's theory a wave function ψ is a matrix of one column with elements $(\psi_1, \psi_2, \psi_3, \psi_4)$. The adjoint matrix $\psi^\dagger$ is a one-rowed matrix with elements $(\psi_1^*, \psi_2^*, \psi_3^*, \psi_4^*)$. Hence $\psi^\dagger\psi$ denotes the inner product of $\psi^\dagger$ and ψ, $\psi_1^*\psi_1 + \psi_2^*\psi_2 + \psi_3^*\psi_3 + \psi_4^*\psi_4$, and $\psi\psi^\dagger$ denotes the outer product—a matrix J whose $\mu, \nu -$ element is

$$J_{\mu\nu} = \psi_\mu \psi_\nu^*.$$

The matrix components of J are given by

$$j_\mu = -\frac{1}{4}\chi(JF_\mu) = -\frac{1}{4}\psi^* F_\mu \psi,$$

the last expression being the chain-product

$$-\frac{1}{4}\sum_{a,b} \psi_a^* F_{(\mu)ab}\psi_b.$$

Tensors which are represented by matrices (with zero characteristic) which are the outer products of two ψ-vectors are called by Eddington "wave tensors." They have a number of interesting properties: the factors of such a wave tensor, say J, ψ, and $\psi^\dagger$, satisfy the wave-equations,

$$(j_1E_1 + j_2E_2 + j_3E_3 + j_4E_4 + j_5E_5)\psi = 0,$$
$$\psi^\dagger(j_1E_1 + j_2E_2 + j_3E_3 + j_4E_4 + j_5E_5) = 0,$$

The following identical relations (first investigated by Darwin) connect the components $j_1, \ldots, j_{45}$:

$$j^2_{10} + j^2_{20} + j^2_{30} + j^2_{40} + j^2_{50} = 0,$$
$$j^2_{15} + j^2_{25} + j^2_{35} + j^2_{45} + j^2_{50} = 0,$$
and
$$j_{23}j_{15} + j_{31}j_{25} + j_{12}j_{35} + j_{50}j_{45} = 0.$$

Let $X = (j_{10}, j_{20}, j_{30}, j_{40})$ and $P = (j_{15}, j_{25}, j_{35}, j_{45})$ be the two 4-vectors contained in J. Let I denote the invariant j_{05} and S the 6-vector $(j_{23}, j_{31}, j_{12}, j_{14}, j_{24}, j_{34})$. Then X and P are at right angles and of equal length $\sqrt{-j_{05}^2}$ and IS equals the vector product of P and X.

This summarises the mathematical analysis underlying Eddington's work. The physical applications will be reviewed in the next number.

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PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London.

The Neutron.—Our knowledge of the neutron, to which reference was made on p. 25 of the July issue of Science Progress, has now been extended by the publication of three papers (*Proc. Roy. Soc.*, **136**, 692, 1932). In the first of these, J. Chadwick deals with the examination of the penetrating radiation emitted when beryllium or boron is bombarded by α-particles from a powerful source of polonium. This radiation is supposed to consist of neutrons, a neutron being assumed to consist of a proton and an electron in very close combination.

The polonium source was placed on one side of a small, evacuated chamber, so that the α-rays could bombard a piece of beryllium on the opposite side of the chamber. The penetrating radiation so produced passed through a thick sheet of aluminium and into an ionisation chamber connected to a valve counter. Deflections of the counter corresponding to particles of considerable ionising power were recorded. These were shown to consist of recoil atoms of the elements, such as

nitrogen, through which the radiation passed. Now the velocity acquired by such an atom, and hence its ionising power, could be calculated on the basis of the neutron hypothesis, and the experimental values were found to be in good accord with such calculations.

Chadwick supposes that the process of emission of a neutron is analogous to the production of a proton in artificial disintegration, and the experimental evidence suggests that the mass of the former probably lies between 1·005 and 1·008, and that the binding energy of the electron and proton which form the neutron is about one or two million electron volts.

In the second of these papers, N. Feather describes an expansion chamber investigation of the elastic and inelastic collisions between neutrons and nitrogen nuclei. He observed that recoil tracks, of maximum length about 3·5 mm. under standard conditions, occurred with considerable frequency; this is in good accord with the neutron hypothesis. About 130 cases of interaction between a neutron and a nitrogen nucleus were observed, and many examples of paired tracks with a common origin were recorded. These were regarded as evidence of a certain kind of disintegration of nitrogen nuclei by neutrons. In this type of disintegration it is supposed that a neutron is captured by, and an α-particle expelled from, the nitrogen nucleus. A second type of disintegration, however, appears to be possible. Here the neutron is not captured, and it appears possible that a proton is expelled from the nitrogen nucleus.

Of thirty-two examples of paired disintegration tracks, twelve were recognised as cases of neutron capture with a fair degree of certainty. They could all be explained on the assumption that an α-particle was expelled, and that the new nucleus so formed was a boron nucleus of mass 11. It may be mentioned that in the case of a disintegration with capture the tracks must be coplanar, and non-coplanar in the case of disintegration without capture.

Disintegrations without capture are rather difficult to explain, and it was assumed that they resulted in the formation of a carbon nucleus of mass 13 and a proton, although the possibility of the production either of a carbon nucleus of mass 12 and a hydrogen nucleus of mass 2, or of a boron nucleus of mass 10 and an α-particle, cannot be excluded. The hydrogen nucleus of mass 2 would be, of course, the isotope of hydrogen H^2, recently reported by Urey, Brickwedde, and Murphy (*Phys. Rev.*, **40**, 1, 1932). The possibility that H^2 may have to be accepted as a unit in the structure of the nucleus means that arguments based on mass-defects and packing fractions will have to be used with greater care, and it looks as if the problem

of nuclear structure is much more complicated than has previously been imagined.

In the third of these papers, P. I. Dee discusses the interaction between neutrons and electrons. A collision between a neutron and an electron would be expected to result in the latter acquiring a velocity up to a maximum of $6 \cdot 6 \times 10^{8}$ cm. per sec. Such an electron would recoil with a maximum range of 3·4 mm. under standard conditions. This is in marked contrast to the range to be expected if the penetrating radiation emitted by beryllium were of the nature of a very hard γ-radiation; for, on the quantum theory, an electron might then acquire sufficient energy to give a range of some metres. Hence the observation of short electron tracks would provide an important, independent test of the neutron hypothesis.

Actually, in his experiments with a Wilson expansion chamber, where special arrangements were made for the detection of individual ions, Dee found that the production of recoil electrons by neutrons occurred very much less frequently than the production of recoil nitrogen atoms. Indeed, it was found that along a neutron track not more than one pair of ions per 3 metres of air was formed; this is about one hundred times less than the number of nitrogen recoil tracks produced.

We see, then, that whilst the new evidence is in favour of the neutron hypothesis, much remains to be done before its effect on the problems of nuclear structure can be properly appreciated.

The existence of an isotope of hydrogen of mass 2, to which reference has been made above, has been confirmed by W. Bleakney (*Phys. Rev.*, **41**, 32, 1932). He has made use of the fact that the triatomic hydrogen ion $(H^1\ H^1\ H^1)^+$ of mass 3 is formed by electron impact at a rate proportional to the square of the pressure, when the pressure in the discharge tube is very low. At the same time the ion $(H^1\ H^2)^+$, also of mass 3, is formed at a rate proportional to the pressure. Hence the two ions can be investigated by means of a mass spectograph, designed for low-pressure work.

The total number of ions of mass 3 was measured per unit electron current in the spectrograph and plotted against the pressure, p. A curve of the form $I = ap + bp^2$ was obtained, and from this the relative numbers of the two ions were found. For a sample of commercial electrolytic hydrogen the ratio of the number of molecules of H^2 to the number of molecules of H^1 was about one in thirty thousand; for a sample concentrated by Urey, Brickwedde, and Murphy, it was about one in a thousand.

The mass of H^2 has been found to be $2 \cdot 01353 \pm 0 \cdot 000064$ by K. T. Bainbridge (*Phys. Rev.*, **41**, 115, 1932), who com-

pared the mass of $(H^1 H^1 H^1)^+$ with He^+ on fourteen spectra, obtained with the mass spectrograph which he recently described (*Phys. Rev.*, **40**, 130, 1932), the masses of helium, hydrogen, and the electron respectively being taken as 4·00216, 1·00778, and 0·00055 on the $O^{16} = 16$ scale. Hence if the H^2 nucleus is composed of one proton and one neutron of mass 1·0067, the binding energy will be somewhat under one million electron-volts, and hence the H^2 nucleus will be loosely bound compared with those of helium and other light atoms.

General Contributions.—Since the publication of the measurements of Busch and of Wolf on the ratio of the charge to the mass of an electron, we have been familiar with the possibility of focusing a beam of electrons by means of a longitudinal magnetic field. As a solenoid carrying a current may be used to bring to a focus a narrow beam of electrons travelling along its axis, we may term this solenoid a magnetic lens.

The question now arises as to whether we can devise an electric lens. This question is answered by Knoll and Ruska (*Ann. der Phys.*, **12**, 607, 1932) in a description of some experiments on the behaviour of electrons and their similarity to corresponding experiments with light waves. They took a spherical condenser and bored holes through the spheres, so that a narrow beam of electrons might pass through the centre and then emerge from the condenser. When the appropriate difference of potential was established between the conductors, the inner one being positive, the radial field of force acted upon an electron beam in much the same way that a converging lens acts upon a beam of light. It is obvious, of course, that owing to the presence of the internal field the velocity of the electrons inside the condenser is different from that outside, although the velocity before entry is the same as the velocity after emergence.

The value of the ratio h/e has been determined by several well-known methods. From the limiting frequency of a beam of X-rays the value $1{\cdot}3705 \times 10^{-17}$ is found. From a determination of the ionisation potential of mercury (*vide* Lawrence, *Phys. Rev.*, **28**, 961, 1926), we get $1{\cdot}37515 \times 10^{-17}$, and, now, we have a new determination by Meibom and Rupp (*Ann. der Phys.*, **13**, 725, 1932). They measured the velocity of a beam of electrons by a method similar to that used by Chaffee and Perry in the latest determination of e/m_0, and they also measured the wavelength of the electrons in the beam by the diffraction pattern produced by a thin gold-foil. The wavelength is connected with the velocity by the de Broglie formula, $\lambda = (h/m_0 \cdot v) \cdot \sqrt{1 - v^2/c^2}$. Since e/m_0 is accurately known, the value of h/e is obtained. In this way Meibom and

Rupp obtained the value $1 \cdot 3798 \times 10^{-16}$, which is supposed correct to about three parts in a thousand.

An interesting experiment in superconductivity is described by Meissner and Steiner (*Zeit. für Phys.*, **76**, 201, 1932), who felt that it might be possible to obtain information concerning the nature of superconductivity by firing slow electrons through a sheet of metal when in the superconducting state. The basic idea was, that since the mean velocity of an electron in superconducting tin corresponds to a fall through 2·4 volts, a beam of slow electrons after passage through the metal surface ought not to be affected by collision with conduction electrons or metallic atoms, and should therefore pass through unimpeded. Accordingly, a beam of slow electrons from an oxide-coated cathode was fired into a tin foil when the latter was in the superconducting state, and also when in the ordinary conducting state. No change was observed; the electrons did not penetrate the superconducting foil.

Meissner (*Ann. der Phys.*, **18**, 641, 1932) also describes another experiment in superconductivity. He took a lead wire and maintained it at a temperature of either 1·3 or 4·2° K, when, under normal circumstances, the wire would be a superconductor. However, by the application of a magnetic field of requisite strength a superconductor may be caused to regain a measurable resistance, when it is far below its normal transition temperature. Accordingly, Meissner measured the resistance of the wire for a series of applied fields, when its temperature was maintained constant at one of the above-mentioned temperatures. In very low fields the wire had a resistance too small to be measured, but at a certain value of the field the resistance suddenly became finite, and continued steadily to increase as the field was increased.

Meissner thus obtained curves of resistance with magnetic field for the temperatures 1·3 and 4·2° K, and by extrapolation to zero field, he obtained values which he regarded as the resistances which the wire would possess at these temperatures if the phenomenon of superconductivity were not present. These extrapolated values, together with values of the resistance obtained in the ordinary way at temperatures outside the range of superconductivity, were plotted on a resistance-temperature graph. The curve obtained corresponded to Grüneisen's T^5 law, between 1·3 and 20° K. Hence, when superconductivity sets in, that portion of the resistance which is some function of the temperature disappears at the same time as that portion which does not depend on the temperature. It will be remembered that those workers who suggest that impurities are responsible for the phenomenon of superconductivity, consider that the impurities raise the resistance until the

transition temperature is reached, when their effect suddenly disappears and the material assumes the low value of the resistance to be expected on the T^5 law. Meissner's latest experiment does not appear to support this view.

A new probe method for the investigation of discharge tube phenomena is described by J. Johannesson (*Ann. der Phys.*, **13**, 953, 1932). He suspends a semicircular wire by one end from a vertical torsion wire. The thickness of the former wire is made as small as possible compared with the mean free path of the gas molecules in the discharge tube. It is so suspended that it forms a portion of an equipotential surface within a cylindrical discharge tube. When it is raised to different potentials with respect to the earthed end of the tube, it becomes charged, and is caused to rotate about the axis of the suspending wire. The deflection is proportional to the difference between the applied potential and that of the region of the tube in which the wire is placed, and to the field in this region. The wire produces little deformation of the field in its neighbourhood, as the applied potentials do not differ appreciably from that of its surroundings. The system possesses a stationary zero. Clearly, when no deflection results, the potential applied is the same as that already established in the tube.

The potential applied to the wire is measured by an electrometer of somewhat new design, of which details must be obtained from the original paper. The current collected by the wire is measured, together with the deflection, and the results are compared with those obtained by the ordinary and the Langmuir probe methods (*cf.* SCIENCE PROGRESS, No. 85, p. 1, 1927). A graphical method is used to determine the exact potential at which no deflection occurs.

The new method gives values of the potential at any point in the discharge tube which are 5 to 25 volts higher than those given by the ordinary probe method, and values about 1 to 3 volts lower than those given by the Langmuir method, *i.e.* it agrees with the Langmuir method within the limits of experimental error. An interesting result of the investigation with the new system, is the discovery that a stream of gas (air) passes from the cathode to the anode. This stream is attributed to the motion of negative ions, and it varies in the striated positive column in a manner opposite to that in which the field varies.

R. Wierl has continued his work on electron diffraction by molecules. In his first investigations (*Ann. der Phys.*, **8**, 521, 1931) he examined about twenty cases of molecules with well-known structures, and showed that the method of examination is simple and gives reliable results. In his latest

paper (*Ann. der Phys.*, **18**, 453, 1932) he has shown that it may be applied to the examination of more complex molecules and for the elucidation of special points of interest to chemists. Indeed, the complete experimental equipment has already been placed on the market by a German firm.

Whereas in the case of scattering of X-rays by gases, the electrons in the molecules play a very important rôle and the nuclei play but little, in the case of electron diffraction by gases, the electrons play very little part and the atomic centres are all-important. Now, the atomic centres are arranged in a definite manner in the molecule, and, consequently, electrons are scattered by a molecule in a way which can be calculated by wave mechanics, if the arrangement of the atoms is assumed and the wavelength of the electrons known. The experimental procedure consists in passing a beam of swift electrons through a fine jet of organic vapour which emerges from a small orifice into a highly evacuated chamber. The electrons are diffracted, and the pattern formed on a photographic plate consists of a number of concentric rings of which the intensity distribution conforms to the distribution of the scattered electrons. The actual distribution can therefore be measured and compared with the calculated distribution. The method is thus very suitable for dealing with isolated molecules in the free state.

Our knowledge of the K series of X-rays of light elements is much augmented by the work of H. W. B. Skinner (*Proc. Roy. Soc.*, **135**, 84, 1932), who has examined the critical potentials of metallic lithium. He finds that they consist of certain low-voltage potentials, with, in addition, three potentials at 53·7, 56·2, and 60·1 volts respectively, which correspond to Li K-radiation. On examining the K-radiation of lithium by the photo-electric method, which he has succeeded in making sufficiently sensitive for the purpose, he finds that it consists of a band, extending to a maximum energy corresponding to 54·1 volts, which is in agreement with the lowest excitation potential for the K-radiation.

The chief interest in this work lies in the comparison of the observed critical potentials recorded above, with the calculated energy levels of the free lithium atom. The critical potential at 53·7 volts may be compared with the radiation potential corresponding to a K to L electron transition in the free lithium atom, which is 53·0 volts. Remembering that the experimental measurements were made with metallic lithium, and not with free atoms, the critical potential at 60·1 volts may be satisfactorily correlated with the calculated ionisation potential of the free atom, namely, 62·5 volts.

The existence of a radiation potential corresponding to a K to L electron transition is rather unexpected, because the L

level would normally be completely filled with electrons. Skinner shows, however, that when an electron is removed from the K level, all the levels are automatically altered in such a way that there are formed empty levels in the atom into which the K electron may move. These L levels, which are, of course, the levels in which the conduction and valency electrons are situated, must have associated with them practically the same energies as the L levels in a free atom. Skinner further suggests that the remaining critical potential, that at 56·0 volts, is the beginning of a series of unresolved radiation potentials, which presumably correspond to electron transitions such as K to M, etc.

Teachers of physics should be much interested in the excellent set of isothermals of hydrogen at temperatures between 0° and 100° C. for pressures up to 1,000 atmospheres, described by Michels, Mjhoff, and Gerver (*Ann. der Phys.*, **12**, 562, 932). Their measurements were made by the method described in *Ann der Phys.*, **87**, 850, 1928, and *Wien-Harms Handbuch der Experimentalphysik*, VIII, 2, 106.

R. W. Gurney has extended his work on the quantum mechanism of electrochemistry by a most useful discussion (*Proc. Roy. Soc.*, **136**, 378, 1932) of that ancient problem, the connection between the Volta contact potential difference and the heat liberated when the solution of the metals in a voltaic cell takes place as an ordinary test-tube reaction. He solves this problem by showing that there is a concealed relation which allows us to prove that the heat liberated in the test-tube reaction is itself determined by the Volta potential difference characteristic of the reacting metals.

He avoids much unnecessary confusion by calling the actual potential difference at a metal-liquid surface the interface potential. In the particular case of a copper rod and a zinc rod dipping into copper sulphate, let the interface potentials be V_c and V_z respectively, and Q_c and Q_z the respective heats of solution of one ion. Then, when one zinc ion displaces a copper ion from the solution, the total heat of reaction is $2e(V_z - V_c) + (Q_c - Q_z)$.

The first term in the last expression is easily shown to be equal to $V_{c\text{-}z}$, the Volta potential difference between the metals, by considering what is taking place around a particle of copper in process of deposition on the zinc rod. Hence, the heat of reaction measured calorimetrically will be $2 \cdot e \cdot V_{c\text{-}z} + (Q_c - Q_z)$. Since, in the general case of any two metals, the second term is usually small compared to the first, the Volta contact potential difference automatically fixes the heat of reaction.

The original paper should be consulted for a full treatment of the general case and the Gibbs-Helmholtz equation, and a

neat dissertation on the application of modern ideas on metallic conduction to the problems of electrolysis.

The Scattering of Hard Gamma Rays.—A series of careful researches on γ-radiation has recently been published by L. H. Gray and by G. T. P. Tarrant. We shall not deal with them in detail, since, for our purpose, it is sufficient to concentrate on their latest publication, a joint paper in the *Proc. Roy. Soc.*, **136**, 663, 1932, on the nature of the interaction between γ-radiation and the atomic nucleus.

Several workers have shown that certain peculiarities are exhibited in the absorption of strongly filtered γ-radiation from thorium C″, both in the magnitude of the absorption and in the way in which it varies with the nature of the absorbing element. These peculiarities have been attributed to interaction between γ-radiation and the nuclei of the atoms of the absorbing material. In the case of absorption in lead, it has been shown that such interaction accounts for 20 per cent. of the total absorbing power of the lead atom. It is roughly proportional to the square of the atomic number of the absorbing element, and appears to increase regularly from element to element. Absorption data obtained with sources of radium (B + C) have also lent support to these conclusions.

The paper to which reference has just been made represents an attempt to describe the nature of this interaction. It therefore discusses the elimination of radiation re-emitted without change of wavelength and of radiation scattered by the Compton process, leaving only the radiation scattered by the atomic nuclei in an absorbing material. A careful study was made of the secondary radiation emitted at angles of 125° and 145° with respect to the direction of the primary radiation, since here the chance of confusion is small, because the Compton radiation is relatively very much weakened by large angle scattering, is thereby considerably softened and therefore easily absorbed, whereas the nuclear radiation is practically unaffected.

The absorption of such secondary radiation from a cylindrical radiator, whose inner surface was exposed to γ-radiation from thorium C″ or from radium (B + C), was studied by using cylindrical sheets of the absorbing material around an ionisation chamber placed inside the irradiated cylinder. The chamber was, of course, shielded from the direct radiation of the source. The logarithm of the intensity of the secondary radiation received by the chamber was plotted against the thickness of the absorber. Curves were thus obtained for the secondary radiation emitted at angles of 125° and 145° when a thorium C″ source was used, and at an angle of 125° when a source of radium (B + C) was used. With lead absorbers the three curves were very similar and approximately parallel to one

another. This clearly means that there was no appreciable difference in the character of the secondary radiation, and that but little Compton radiation was present. Consequently, it is presumed that the absorption of a quantum of the primary radiation leaves the nucleus in an excited state, and that the secondary radiation examined by Grey and Tarrant is really a characteristic radiation emitted by the nucleus when it returns to its normal state.

In order to make further progress, it is provisionally assumed that there is some threshold frequency above which such interaction is possible. The value of this threshold frequency cannot be deduced from absorption measurements, unless some further assumption is made as to the manner in which the nuclear absorption coefficient varies with the wavelength of the primary radiation. It is therefore provisionally assumed that this coefficient is zero on the long-wave side of the threshold, and that it decreases continuously with the wavelength on the short-wave side. Then, from the distribution of energy in the radium C spectrum, it is estimated that the threshold wavelength is 7 X·U, which corresponds to a quantum of 1·8 million electron-volts.

This estimate agrees with that of Chao (*Proc. Roy. Soc.*, **135**, 206, 1932), obtained from measurements of the absorption coefficients in lead and other elements with roughly monochromatic γ-rays of various wavelengths between 4·7 and 9·3 X·U. It also receives an independent check from observations on the relative intensities of the characteristic radiations excited by thorium C″ and radium C radiations, which we will not discuss here. It is an important fact that the value of the threshold wavelength appears to be the same for tin as for lead.

It is found from an examination of the total nuclear radiation from lead that each excitation of a lead nucleus is followed by the emission either of one quantum of hard radiation of $h\nu = 0{\cdot}92$ million electron-volts approximately and one quantum of softer radiation of $h\nu = 0{\cdot}47$ million electron-volts, or of three quanta of the softer radiation, assuming the emission to be spatially isotropic.

A series of experiments was also carried out with tin, iron, and water (virtually, oxygen) as radiators, and it was found that the absorption curve in lead changed but very little from substance to substance. Incidentally, the secondary radiation from the walls of the room, for which correction was made, was of nuclear origin, since it exhibited the same absorption curve as the radiators.

The analysis of the absorption curves of lead and tin shows that the quanta of the characteristic radiations are practically the same for both, and it is therefore supposed that the same

radiations are emitted by the two nuclei. This would account for the similarity of the absorption curves from different radiators.

It appears that the fraction of the primary radiation which is transformed into characteristic radiation is the same for all the radiators. Consequently, it is concluded that in all cases the absorption of a quantum of 2·65 million electron-volts from thorium C″ excites the nucleus, and causes the subsequent emission of quanta amounting to 1·4 million electron-volts. There remains, then, some energy to be accounted for. The proportions of the two components, *viz.* 0·92 and 0·47, which constitute the secondary radiation, vary from element to element, so that they must be regarded as alternative modes of emission.

Gray and Tarrant give a tentative representation of the excitation process in terms of energy levels. To give a picture of the emission process it is important to know how the excited nucleus disposes of the excess energy not accounted for in the secondary radiation. It is important, for instance, to know whether it may emit a quantum of soft radiation, which would be selectively absorbed in lead, and therefore difficult to detect. It appears fairly certain that the radiation of the same wave-length as the primary radiation is not re-emitted.

As the oscillating units responsible for the secondary emission the α-particles in the nucleus are suggested. This would explain why the secondary radiation is proportional to the square of the atomic number, and why it is the same from different elements. The individual protons in the α-particle could then be regarded as the individual oscillators, but further speculation at this stage does not appear to be desirable.

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., University, Glasgow.

Petrology—the Igneous Rocks.—The first volume of Prof. Johannsen's new textbook has now been published (*A Descriptive Petrography of the Igneous Rocks.* Vol. I: Introduction, Textures, Classifications, and Glossary. Univ. of Chicago Press, 1931, 267 pp., 145 illustrations). Following a general introduction there come chapters on the constituents, structures, textures, and classifications of the igneous rocks. The bulk of the book deals impartially with various modes of classification. The magmatic classifications of Osann, C. I. P. W., Hommel, Niggli, and von Wolff, the various qualitative and quantitative mineralogical systems, and finally Johannsen's own quantitative mineralogical system, are passed in review. A most valuable glossary of general and textual terms is given, along with some useful tabular matter. The book provides magnifi-

cent illustrations of textures, and photographs of the pioneers of petrography along with petrographers prominent in classificatory work.

In a most valuable memoir on "Die quantitative mineralogische Klassifikation der Eruptivgesteine," Prof. P. Niggli (*Schweiz. Min. Petr. Mitt.*, vol. XI, 1931, pp. 296–364) makes a much-needed distinction between the classification of magma-types on the one hand, and rock-types on the other. After some penetrating criticism of the bases of Johannsen's system, he proposes modifications which tend, in his opinion, to bring it more into harmony with Rosenbuch's familiar and more "natural" scheme of classification, and to supply the latter with the quantitative basis the lack of which was its chief defect. In our opinion Niggli's is the best quantitative mineralogical classification of igneous rocks which has yet been proposed.

Johannsen briefly replies to Niggli's criticisms of his system of classification in a paper entitled, "Die quantitative mineralogische Klassifikation der Eruptivgesteine" (*Centr. f. Min.*, Abt. A, 1932, No. 5, pp. 146–51).

In a paper on "Classification of Igneous Rock Series," Dr. M. A. Peacock (*Journ. Geol.*, vol. XXXIX, 1931, pp. 54–67) points out that some rock series cannot properly be classed either as alkalic or sub-alkalic. To meet such border-line cases as these he proposes a fourfold division into alkalic, alkali-calcic, calc-alkalic, and calcic groups. From a graphical representation of thirteen rock series it is shown that the silica value at which the curves for total alkalis and for lime intersect (the alkali-lime index) is characteristic of a rock series, and can be utilised to delimit the above four groups, in which certain diagnostic minerals must also be present.

Prof. P. Niggli has provided a useful summary of his views on mineral provinces and paragenesis in the second edition of a German dictionary of science (*Handwörterbuch der Naturwiss.*, vol. VI, 1931, pp. 1028–33).

Dr. E. Tröger ("Zur Sippenteilung magmatischer Gesteine," *N.J. f. Min.*, *B.-B.*, 62, Abt. A, 1930, pp. 249–330) has added one more to the endless procession of magmatic projection systems. He indicates analyses by a point within a "differentiation-cube," the sides of which measure the "acidity" (relation of silica to metallic oxides), the relations of alkali-feldspars and feldspathoids to anorthite, and the relation of potash to soda feldspars (or of leucite to nepheline). A differentiation series is indicated by a line within the cube. By this statistical method he comes to the rather trite conclusion that the Atlantic and Pacific kindreds (sippen) in Becke's original sense are thoroughly substantiated. He erects, however, a third

kindred—the Predazzian—which stands midway between the other two. Three sub-kindreds are established: the Mediterranean, to accommodate highly potassic basic rocks; the anti-Mediterranean, for highly sodic acid rocks; and the anorthositic sub-kindred.

A valuable compilation of chemical analyses of igneous rocks, metamorphic rocks, and minerals, mainly from British localities, has been made from the Geological Survey records by Miss E. M. Guppy and Dr. H. H. Thomas (*Mem. Geol. Surv. Gt. Britain*, 1931, 166 pp.). Petrographical descriptions have been written by the last-named author. The volume concludes with a discussion of Methods of Analysis by F. R. Ennos and R. Sutcliffe, which is a distinct contribution to the difficult subject of rock analysis.

W. Larsson has similarly provided petrographers with a very useful compilation of analyses of Swedish rocks—igneous, sedimentary, and metamorphic (*Bull. Geol. Inst. Upsala*, vol. XXIV, 1932, pp. 47–196). He makes an interesting statistical comparison of the analyses of granites and leptites, and shows that the latter have undoubtedly been subjected to secondary chemical alterations, mainly a magnesia metasomatism. Some halleflintas, however, indicate an early intermingling of calcareous and clayey sedimentary matter with the original acid tuffs.

In a discussion of the ophitic texture and the order of crystallisation in basaltic magmas, T. Krokström (*Bull. Geol. Inst. Upsala*, vol. XXIV, 1932, pp. 197–216) defends the original interpretation of ophitic texture that the plagioclase has crystallised distinctly earlier than the pyroxene, in opposition to the view of Bowen and Fenner that the two minerals concerned have crystallised simultaneously. The best development of ophitic texture was found in olivine-bearing dolerites. From this Dr. Krokström goes on to consider fractional crystallisation and rock genesis, and concludes with a doubt as to the universal validity of Bowen's principle of crystallisation differentiation.

Dr. T. W. F. Barth (*Amer. Min.*, **16**, 1931, pp. 195–208) presents evidence that the common pyroxene of the basaltic rocks of the Pacific, the Brito-Icelandic province, and other regions, is the variety rich in clino-enstatite and clino-hypersthene which is known as pigeonite. He also shows that the early phenocrystic pyroxenes of basalts are usually poorer in the enstatite and hypersthene molecules than the later ground-mass pyroxenes. Pyroxenes crystallising from basaltic magmas thus exhibit a regular sequence of crystallisation from diopsidic to hypersthenic varieties, during which the content of $MgSiO_3$ may remain constant or slightly increase.

Basing his views on the study of the North Nyassa igneous province, and on the basalt of Stöffel (Westerwald), Dr. E. Lehmann (" Beziehungen zwischen Kristallisation und Differentiation in basaltischen Magmen," *Min. Petr. Mitt.*, **41**, 1931, pp. 8–57) concludes that there is a definite relation between crystallisation and differentiation in basaltic magmas. The initial basaltic magma in the above province yields three heteromorphic rock types, essexite-basalt, atlantite, and hornblende-basalt, of similar chemical compositions, and giving similar norms. If the initial crystallisation produces essexite-basalt, the subsequent course of differentiation yields trachydolerite and trachyte; an atlantite crystallisation favours tephritic and phonolitic differentiates. Data are wanting in the case of hornblende-basalt crystallisation, but it is believed to yield trachyandesite and kenyte differentiates. No hint is given as to the nature of the physical factors that influence the initial mode of crystallisation and therefore the subsequent differentiation. A penetrating review of this memoir is given in the *Geol. Mag.*, vol. LXVIII, 1931, pp. 189–90.

Dr. C. N. Fenner follows up his first article voicing doubts as to the effectiveness of crystallisation-differentiation in many of the cases in which this process has been cited (SCIENCE PROGRESS, April 1931, p. 581) by a second entitled, " The Residual Liquids of Crystallising Magmas " (*Min. Mag.*, vol. XXII, 1931, pp. 539–60), taking as his text a recent paper by Dr. F. Walker on a tholeiitic phase of the quartz-dolerite magma of Central Scotland (SCIENCE PROGRESS, *cit. supra*). His chief point, as before, is that the crystallisation residues of basaltic magmas are rich in iron, and are therefore incompatible with the orthodox theoretical view that the residues should be of granitic composition. In a paper on the origin of granitic magmas (cited below), Prof. P. Eskola points out, however, that granitic magmas *are* relatively rich in iron. Compared with basalts they are enriched in soda as compared with lime, but far more so in iron as compared with magnesia; but these enrichments are masked by their enormous augmentation of potash and silica. If granite analyses are recalculated to 100 after the normative free silica and potash feldspar have been deducted, the enrichment in soda and iron relatively to lime and magnesia becomes clearly apparent. Eskola further points out that the residual liquid from basaltic crystallisation cannot be expected to give granite at once, for a granitic liquid is the end-product of long-continued fractionation during which basic silicates such as hornblende and biotite crystallise out in dioritic and granodioritic stages, leaving residues progressively enriched in potash and silica.

The problem of the association of acid and basic rocks in

central complexes such as those of the British Tertiary province is illuminatingly dealt with by Prof. A. Holmes (*Geol. Mag.*, vol. LXVIII, 1931, pp. 241–55). A significant contrast between oceanic and continental igneous complexes is pointed out; oceanic basalt magmas differentiate with production of trachyte or syenite magmas, but continental basalts generally give the acid-basic association, in which micropegmatitic quartz-dolerites are very common. This contrast is correlated with the differences in composition between oceanic and continental sectors. Two main generalisations are thereby suggested: (1) normal world-wide differentiation of basaltic magma is towards the generation of trachyte; (2) granitic magma is produced only when the igneous complex has developed through the sial layer of the crust. The co-existence of acid and basic magmas, with only subordinate amounts of intermediate material, is characteristic of the last-named type of development. Prof. Holmes propounds an ingenious theory of heat transfer due to convective circulation in magma cupolas to account for the fusion of the granitic layer in the upper parts of the cupolas. Granitic material might be developed at the top of the magmatic column while normal differentiation brought about the basalt-trachyte association in their lower portions. The magmatic history of the Tertiary ring complex of Ardnamurchan is shown to be in accordance with this theory of cupola development.

One of the side issues of Prof. P. Eskola's masterly paper on "The Origin of Granitic Magmas" (*Min. Petr. Mitt.*, **42**, 1932, pp. 455–81) is dealt with above. Its main subject is the formation of granitic magma in connection with orogenic movements by a pressing-out, squeezing, or filtration of the low temperature components, partly from more basic magma not yet fully crystallised, and partly from rocks undergoing differential re-fusion in the deeper regions of the geosynclines. In kratogenic regions, as distinct from the orogenic zones, granitic magma is formed in subordinate amount by differentiation from basaltic or gabbroidal magmas. Certain points in the above thesis are illustrated by a description of the great olivine-diabase sill with its pegmatoid "pipes" on the island of Säppi in West Finland, and by a discussion of Rapakiwi types of granite. Eskola also points out that many solid residues after differential re-fusion must be of extreme composition, discusses the question why the sima layer is nowhere exposed, and sketches the "earliest history" of the earth in the light of his theory.

The subject of the second half of Part III of the late Prof. J. H. L. Vogt's exhaustive memoir on, "The Physical Chemistry of the Magmatic Differentiation of Igneous Rocks" (*Norske Vidensk.-Akad. Oslo, I. Math.-Nat. Kl.*, 1930, No. 3, 1931,

242 pp.) is the granitic rocks. Vogt's well-known statistical methods are employed in association with a penetrating physicochemical analysis of magmatic processes. He contrasts *shallow* deep-seated granites, such as those of the West of Scotland, with their residual dikes of aplite, miarolitic druses, their lack of pegmatites, myrmekite, and primary muscovite, with *ultra* deep-seated granites, such as those of the Archæan in Norway, which are rich in pegmatite and myrmekite, and are poor in aplites, miarolitic druses, etc. This contrast is explained as due to higher content of magmatic water in the latter class. Vogt comes to the conclusion that granites are residual magmas formed by the crystallisation-differentiation of more basic rocks.

In his paper " Die Genesis der Granite physicochemisch gedeutet," Vogt (*Zeit. Deutsch. Geol. Ges.*, **83**, 1931, pp. 193–214) reasserts the view that granites are the results of differentiation in the " rest-magma " direction, and that alkali granites with about 75 per cent. of silica are the end-products. He shows that the temperature interval of crystallisation of the mineral components steadily diminishes in the series, quartz-diorite—granodiorite—calc-alkali granite—alkali-granite ; and in harmony with this granites, and especially alkali-granites, usually belong to the latest epoch of eruption in any given co-magmatic province. Vogt does not consider the formation of granites by anatexis or palingenesis.

Prof. Vogt further deals with the physical chemistry of the sequence of crystallisation in magmas with special reference to granites in a paper entitled, " On the Terms Eutectic, Cotectic, Peritectic, Anchi-eutectic, Anchi-cotectic, etc., and their Importance in Petrogenesis " (*Journ. Geol.*, vol. XXXIX, 1931, pp. 401–31). He proposes to replace the term " eutectic curve " by a new term, " cotectic curve " ; and gives an excellent summary of the physical chemistry of magmatic crystallisation in dealing with the other terms mentioned in the title.

The paper by Dr. A. Brammall and Dr. H. F. Harwood on " The Dartmoor Granites : their Genetic Relationships " (*Quart. Journ. Geol. Soc.*, vol. LXXXVIII, 1932, pp. 171–237), which, we think, is destined to become a petrological classic, deals with the origin, intrusion-history, and space-form of the Dartmoor Granite Complex, with the aid of unusually numerous field, microscopical, and analytical data. The variation of the complex engages a silica range of 55–75 per cent., and the rocks vary from sub-melanocratic facies rich in biotite to biotite-free leucocratic types. As a whole the suite has many alkaline characteristics. The variation is basic to acid from (*a*) east to west, (*b*) centre to margin, (*c*) a low to a high horizon in the same porphyritic biotite-granite, and (*d*) early to late intrusions.

The older granites are locally underlain and injected by more acid and more basic variants.

The observed variation is ascribed to basification of initially acid magma, while emplacement and differentiation were proceeding. The study of inclusions and contact-facies shows that the basic material consisted of country-rocks akin to the diabases, spilites, and shales surrounding the granite. Quantitative assessment of assimilation has been found possible by the study of certain minerals (cordierite, garnet), and of chemical data concerning indicators such as alumina, alkalies, magnesia, iron oxides, and baryta. A reciprocal granitisation of the xenoliths has taken place, evolving hybrids ranging from rocks resembling hornblende-diorite to rocks similar to biotite-granite. The proved phenomena of assimilation thus show that the Dartmoor granites are essentially hybrid, but to a varying extent.

The Dhoon (I.O.M.) Granite, according to S. R. Nockolds (*Min. Mag.*, vol. XXII, 1931, pp. 494–509), is also essentially hybrid. It contains numerous clots consisting of biotite in association with any or all of the following minerals: zoisite, ilmenite, sphene, epidote or clinozoisite, and garnet. It is shown by chemical and microscopical examination that these clots represent the last remnants of basic greenstones which have been absorbed by the granite. Altered xenoliths of these rocks are found, and all stages in their dissolution to biotite clots can be followed. The evidence points to an extensive interchange of oxides between the original alkali-granite magma and the basic inclusions.

A paper on "The Rock Groups of Jersey, with Special Reference to Intrusive Phenomena at Ronez," by A. K. Wells and S. W. Wooldridge (*Proc. Geol. Assoc.*, vol. XLII, 1931, pp. 178–215), describes very similar phenomena to the foregoing. The Ronez Granite has been injected into gabbro in some places, and shattering due to immersion of cold xenoliths in hot magma, and subsequent gradual assimilation, is well shown by a continuous series of observations, from angular fragments at one end to "ghosts" whose original xenolithic character is inferred from a slight darkening of colour and richness in coloured minerals in an otherwise normal granite, at the other.

H. H. Thomas and W. Campbell Smith have described "Xenoliths of Igneous Origin in the Trégastel-Ploumanac'h Granite, Côtes du Nord, France" (*Quart. Journ. Geol. Soc.*, vol. LXXXVIII, 1932, pp. 274–96). This red porphyritic granite contains vast numbers of inclusions, a few of ordinary hornfels, but the great majority of "basic segregations" which are shown to have had their origin in an earlier mass of olivine-norite. The roof of the granite consists of basic igneous rock

of very patchy character, highly variable in composition, and obviously much hybridised. This material, which has supplied the xenoliths, is believed to represent the effects on the original ultrabasic igneous rocks of that part of the granite magma which was still fluid or volatile at the time.

The syenite of Radauthal, one of the rare occurrences of this rock in the granite-gabbro region of the Brocken massif (Harz), is now regarded by O. H. Erdmannsdorfer (*Abh. d. Heidelberger Akad. Wiss., Math.-Nat. Kl.* **15**, Abh., 1930, 61 pp.) as a palingenetic igneous rock. Its composition is abnormal, only one of its later pyroxene-syenite differentiates approximating to an igneous type. The syenite is regarded as due to the re-melting and re-solution of "orthophyre-hornfels" by the action of a gabbroidal magma.

A dolerite sheet intrusive into granite near Marandellas, Southern Rhodesia, which exhibits marked marginal assimilation, is described by L. Thornton (*Trans. Geol. Soc. S. Afr.*, **33**, 1931, pp. 31–47). The granite has been basified by the addition of hornblendic and feldspathic material, and micropegmatite has been formed in the dolerite. The dolerite sheet consists of an upper layer carrying much micropegmatite, a median layer of peridotite, and a thin basal zone of olivine-dolerite. An hypothesis involving the intrusion of two successive magmas, one of olivine-dolerite partly differentiated, and a second of peridotite which was in almost a solid condition as shown by its protoclastic structure, is favoured.

Early experiments suggested that granite melted or crystallised at higher temperatures than basalt. The question is discussed by J. W. Greig, E. S. Shepherd, and H. E. Merwin (*Ann. Rept. of the Director of the Geophys. Lab., Carn. Inst., Washington, Year Book No.* 30, 1931, pp. 75–8) in the light of some new experiments which indicate that rocks of granitic composition—granites, rhyolites, and obsidians—when heated in the laboratory so that they are essentially free from volatiles, melt completely at equilibrium at lower temperatures than basalts correspondingly free from volatiles. To produce the same degree of melting under certain given conditions basalts required to be heated to temperatures about 300° higher than granites. The bearing of these experiments on tectonic theories based on the thermal condition of the earth's crust, is obvious.

The experiments of R. W. Goranson on the melting of granite (*Amer. Journ. Sci.*, **23**, 1932, pp. 227–36) indicate that Stone Mountain (Georgia) granite becomes completely liquid, except for hæmatite, at a temperature of 700° ± 50°, and under a pressure of 1,000 bars. The melt has 6·5 per cent. of water in solution. From these and other experimental facts it has been calculated that a granite magma containing 1 per cent. of water

in solution at a depth of 10 km. would begin to crystallise at 1025°. At 700° 85 per cent. of the original magma would have crystallised, and the residual liquid would contain 6·5 per cent. of water in solution. This residual solution would be available for the formation of aplites, pegmatites, and quartz veins; two-thirds of it would crystallise between 700° and 500°. Of the original magma the final products would be 85 per cent. of granite (1025–700°), 10 per cent. of aplite and pegmatite (700–550°), and 5 per cent. of quartz veins (500° and lower).

The first volume of A. E. Fersmann's monograph on pegmatites, unfortunately written in the Russian language, deals with the granite-pegmatites (*Pegmatites: Characters, Geochemistry, Distribution, and Uses. Vol. I: Granite-pegmatites*, 1931, 604 pp.). A good summary of the work is given in *Geol. Centralbl.*, **47**, 1932, pp. 273–5, and Fersmann has explained his views in two papers dealt with below. A second volume, dealing with pegmatites of the basic rocks, especially with those of the syenites and nepheline-syenites, is in preparation.

In a paper, "Über die geochemisch-genetische Klassifikation der Granitpegmatite," A. E. Fersmann (*Min. Petr. Mitt.*, **41**, 1931, pp. 64–83) states that pegmatite formation takes place in three connected stages—magmatic, pegmatoid, and hydrothermal—the whole range being further divisible into ten temperature stages. Regular sequences of crystallisation in each stage yield characteristic pegmatite types which are arranged in three main series—a pure or normal line, a contact line, and a migmatitic line. Pegmatites are regarded as magmatic residual solutions which exhibit a regular course of evolution by gradual precipitation on the one hand, and distillation of volatile constituents on the other, from a molten magmatic region, through a fluid, pegmatoid-pneumatolytic stage, to final hydrothermal products. The crystallisation of granite pegmatites occurs approximately between 800° and 100°.

In a further paper, "Zur Geochemie der Granitpegmatite" (*Min. Petr. Mitt.*, **41**, 1931, pp. 200–14), Fersmann shows that granite pegmatites consist of 63 elements, of which only 20–25, at most 30, play an important part, and are considered as the typomorphic elements of granite-pegmatite processes. In these elements there is a predominance of those with odd atomic numbers, of oxides with an odd number of oxygen atoms, especially the sesquioxide, R_2O_3, also R_2O_5, and R_2O, and of minerals whose crystal axes are trigonal or anchi-trigonal. The numbers of minerals capable of formation in pegmatites is limited by the operation of the phase rule, and of the law of double compounds.

In a paper by D. R. Derry on "The Genetic Relationships of Pegmatites, Aplites, and Tin Veins" (*Geol. Mag.*, vol. LXVIII,

1931, pp. 454–75), it is suggested that pegmatites and aplites are formed by squeezing during the crystallisation of granitic residual liquors, aplites representing the crystallised portions, and pegmatites the highly aqueous liquid residues. Albite, along with rare elements and their compounds, remain in solution to a later stage, and replace the earlier minerals as the final liquids migrate up the dikes and sills of common pegmatite. Cassiterite, probably carried as a volatile compound, tends to be deposited in the uppermost parts of the dikes and sills. The presence of tin veins or stanniferous pegmatites within a granite region depends on the depth of erosion, tin veins being found when only the summits of the cupolas rising from the batholith are exposed. Common pegmatite, devoid of tinstone, occurs where erosion has been deep enough to cut into the actual top of the batholith. Tin-bearing pegmatites, however, appear at intermediate levels.

According to T. W. Gevers and H. F. Frommurze ("The Tin-bearing Pegmatites of the Erongo Area, South-West Africa," *Trans. Geol. Soc. S. Afr.*, **32**, 1930, pp. 111–49), the great majority of the numerous pegmatites of South-West Africa belong to two types: tourmaline pegmatites, and tin-bearing pegmatites. They occur in granite phacoliths which were intruded during active folding of the ancient sediments. The authors deal almost entirely with the tin-bearing pegmatites of which many different types occur. The source of the metalliferous vapours and solutions is the same as that of the pegmatites in general, and the deposits are genetically connected with the intrusion of the "old" granites, and have nothing to do with the much younger Erongo Granite of the same region.

At Palabora (Eastern Transvaal) a remnant of marmorite (crystalline limestone) is separated by pyroxenites rich in apatite, and pyroxene-syenites, from a large surrounding mass of granite. While S. J. Shand (*Trans. Geol. Soc. S. Afr.*, **34**, 1931, pp. 81–105) regards the pyroxene-syenites as due to syntexis between granite and limestone, he finds that the pyroxene-apatite rocks have arisen by gravitative differentiation from the syenites. Since the pyroxenite is potash-bearing, and the syenite is soda-rich, this process requires the elimination of soda, which is believed to have been carried upwards along with liberated carbon dioxide.

A. L. du Toit, however (*ibid.*, pp. 107–27), brings forward evidence to show that the pyroxenite-syenite complex has been formed by direct additive metamorphism by the granite magma and its emanations upon a mass of siliceous dolomitic limestone practically *in situ*. The poverty of the pyroxenite in soda and its richness in silica, potash, and volatiles, suggest that the

reacting melt corresponded to aplite or pegmatite rather than to normal granite.

Dr. J. Phemister has demonstrated that the so-called limestone at Bad na h'Achlaise, Assynt, Sutherlandshire (*Summ. Prog. Geol. Surv. for* 1930, Pt. III, 1931, pp. 58–61), which has been used to support the hypothesis of limestone syntexis in the Loch Borolan igneous complex, is really a carbonated ultrabasic igneous rock (cromaltite). The occurrence thus falls into place with those of the Fen (Norway) region described by Brögger and later by Bowen.

BOTANY. By Prof. E. J. SALISBURY, D.Sc., F.L.S., University College, London.

Ecological.—The distribution of the two species of *Hutchinsia*, *H. alpina* and *H. brevicaulis* is of considerable interest, since *H. alpina* is mainly found on calcareous soil, whereas *H. brevicaulis* is chiefly met with on siliceous soil. G. Melchers has recently studied their distribution in detail, and from an examination of the *p*H values in a number of stations finds that the localities occupied by *H. alpina* are in general only slightly more alkaline (mean values: *H. alpina*, *p*H, 7·34; *H. brevicaulis*, *p*H 7). Cultures indicate that both species are stimulated by the presence of calcium carbonate, and that growth is depressed by increased acidity (*Oster. Bot. Zeit.*, pp. 81–103, 1932).

Experiments on assimilation in shade under natural conditions have been made by K. Hiramatsu (*Sci. Rep. Tohoku Imp. Univ.*, pp. 239–57, 1932). He finds that the shade leaves of "sun-plants" usually assimilate more slowly than the shade-plants themselves. Both showed a marked decrease in the rate of assimilation at midday, followed by an afternoon rise, which was found to be much more marked in the shade species than in the sun species. In the same journal (pp. 129–30) Tadso Timbo reports the study of the pollen content of peat from Mt. Hakkoda, N. Japan. The present vegetation is a Molinietum, but this would appear to have succeeded coniferous forest, which was itself preceded by deciduous forest.

An interesting account of the cause of dormancy in the seeds of *Melilotus alba* is furnished by D. H. Hornby (*Bot. Gaz.*, pp. 345–75, 1932), who finds that the hard seeds are due to a continuous layer formed by the suberised caps of the so-called Malpighian layer which prevents absorption of water. "Soft" seeds are due to a cleft in this layer in the strophiolar region. In "hard" seeds the Malpighian layer in the strophiolar region is in a state of tension, and slight impacts in this region are sufficient to cause rupture and consequent permeability. Shaking seeds in a bottle was found sufficient to increase the

number of permeable seeds from 0·5 per cent. to 91 per cent. Soft seeds of various other species, *e.g. Trifolium arvense, T. hybridum, T. pratense, Medicago lupulina* and *M. sativa* were also found to be associated with a permeable area at the strophiole.

The studies of Starkey on the influence of higher plants on the micro-organic population of the soil (*Soil Science*, **32**, 1931) have shown that the bacterial flora of the soil tends to augment with proximity to the roots of higher plants. Thom and Humfield, in a similar study (*Soil Science*, pp. 29–36, 1932), confirm Starkey's results, and indicate that the roots tend to maintain their own reaction in the immediate vicinity and thus establish an environment favourable to micro-organisms.

Clark and Shive have grown tomato plants in culture solutions with and without continuous aeration, and find that in the absence of aeration the root system attains less than two-thirds the dry weight of the root systems on aerated culture solutions. But the increase in top growth is proportionately greater with aeration, so that in non-aerated cultures the root system is *proportionately* better developed, having regard to the shoot system which it supplies (*Soil Science*, pp. 37–40, 1932).

Cytology, etc.—San criticises adversely the supposed mechanism of crossover supported by Belling, Darlington, and Maeda, and from a consideration of the chromosomes of *Callisia repens* and of chiasma frequency in other plant genera finds support for the hypothesis that crossing-over is caused by breaks in two of the chromatids at a chiasma (*Jour. Arnold Arboretum*, pp. 180–212, 1932).

H. Witsch (*Oster. Bot. Zeit.*, pp. 108–41, 1932) records the chromosome numbers for twenty-two species of Rhinantheæ. The more interesting of these are: *Pedicularis palustris*, $2n = 16$; *Bartsia alpina*, $2n = 24$; *Odontites serotina*, $2n = 20$; *O. verna*, $2n = 40$; *Euphrasia rostkoviana*, $n = 11$; *E. Salisburgensis*, $n = 22$; *Melampyrum arvense, M. sylvaticum, M. pratense*, $2n = 18$, $n = 9$; *Lathræa squamaria*, $2n = 36$ ($n = 18$).

G. Nakajima finds that in three species of *Quamoclit* the somatic number of chromosomes is 28, in another species 30, and in *Q. slateri* 58. For the last-named species Kano reported $2n = 60$, but the number here recorded is in harmony with the view that this species is a hybrid derived from *Q. pennata* ($2n = 30$) and *Q. coccinea* ($2n = 28$) (*Tokyo Bot. Mag.*, p. 7, 1931).

Sporogenesis in *Begonia* has been studied by Pastrana (*Amer. Jour. Bot.*, pp. 365–82, 1932), who finds that an unpaired chromosome is present in the pistillate flowers and absent from the staminate flowers. *Begonia Schmidtiana*, the species studied, would thus appear to possess, like *Elodea, Rumex,*

Humulus, and *Melandrium*, an accessory sex chromosome. In the linear tetrad of megaspores of the species investigated the two at the micropylar end carry seven chromosomes each, and the remaining two six chromosomes. The odd chromosome is found in the embryo sac in the nucleus of the egg. This sex chromosome fails to enter the stem initial from which the staminate flower develops.

The occurrence of a spherical megaspore tetrad in *Villarsia nymphoides* is recorded by Stover (*Bot. Gaz.*, pp. 474–83, 1932).

Two new species of *Euphrasia* have been described by du Reitz from the Philippines, and in relation to these he discusses the geographical distribution of the genus as a whole. They are closely related to the Formosan species, and less closely to the Bornean species, which in turn has close affinity with the species of New Guinea, linking up with those of Australia and New Zealand. The genus as a whole presents two centres in the southern hemisphere, namely, in Australasia and in South America, the link between which is held to be via the antarctic continent. The species here described clearly form, with the Formosan and Malayan species, a transition series connecting the southern hemisphere centre and the boreal centre. Such bi-polar distributions are held to be a result of the transtropical bridges furnished by the Andean ridge in the New World and the Malayan-Papuan bridge in the Old. Of these two migration routes the genus *Euphrasia* is held to have travelled via the latter only since the South American and Juan Fernandez species are allied to the Australian and not to the North American species (*Svensk. Bot. Tids.*, Bd. 25, H4. 1931).

Anatomy.—An investigation of the epidermis of the Gramineæ is reported at length by H. Prat (*Annals des Sci. Nat.*, pp. 117–325, 1932). The author attributes considerable taxonomic value to the epidermal characters which, despite the marked differences that may obtain in different environments, are stated to retain their qualitative distinctions. In some plants such as *Poa annua* the epidermis is relatively undifferentiated, and there is little difference between its structure in the basal and uppermost leaves. In others, *e.g. Psamma arenaria*, there is marked differentiation and a gradation from base to apex, and this difference is considered to be correlated with the stage at which the reproductive shoots become differentiated. The characters on which reliance is placed are whether or no the epidermal cells are differentiated into long and short cells. Whether the elongated cells have straight or sinuous walls and bear papillæ or more pronounced appendages. If short cells be present, whether these are silicified or suberised and are developed above the general epidermal level or not. The French species of *Agropyrum* are studied from the standpoint

of their epidermal characters, and the value of these for purposes of classification is shown.

Five types of medullary bundles in the stem of the Ranunculaceæ are recognised by M. Kumazawa (*Tokyo Bot. Mag.*, vol. XLVI, p. 260, 1932). In *Thalictrum* spp. the medullary bundles are leaf trace strands. In *Anemone japonica* perianth strands also contribute to the medullary system. In *Hydrastis* the medullary bundles are leaf traces, but do not enter the pith till the second internode below the leaf insertion. In *Podophyllum* the perianth segments form medullary bundles which extend throughout the pith. Finally, in *Cimicifuga* the leaf traces are subordinate to the cauline and lateral shoot traces which constitute the dominant system.

An investigation into the variation in size of the Xylem elements in different parts of the same tree has been reported by H. E. Desch. In the same annual ring the fibres showed an increase in length with increasing height in the tree up to a maximum followed by a decrease. A high degree of positive correlation was found between cell size and the width of the annual ring at a given height on the tree, whilst the specific gravity at a given height increases from within outwards and subsequently falls (*New Phytologist*, pp.73–118, 1932). In the same journal Miss Chattaway describes the wood-parenchyma types in the tribe Sterculieæ, and concludes that *Tarrietia* and *Heritiera* should, on anatomical grounds, be excluded from this tribe. Three types of vertical parenchyma types are recognised. The first type with very little parenchyma and but slight aggregation into tangential bands is associated with the longest vessel segments (404–560μ). The second type shows clearly distinguished tangential bands of parenchyma, usually 1 cell wide (rarely 2–3); this is associated with vessel segments of medium length (311–427μ). The third type has broad bands of parenchyma and short vessel segments of from 256–377μ. If Frost's views regarding segment length and primitiveness be accepted, the last-named would be the most specialised type.

PLANT PHYSIOLOGY. By Prof. Walter Stiles, Sc.D., F.R.S., The University, Birmingham.

Water Relations of the Plant.—The various problems connected with the relations of the plant to water, such as absorption by the root, conduction of water through the plant, and transpiration from the leaves, have attracted much attention during recent years, and in the following pages reference can only be made to a selection of the many interesting researches dealing with such problems. Firstly may be noted a paper by P. J. Kramer on "The Absorption of Water by Root Systems of Plants" (*Amer. Journ. Bot.*, **19**, 148–64, 1932), in which are

recorded the results of experiments performed with a view to shedding light on the part played by the living cells of the root in the absorption of water and the development of so-called root pressure. The work involved falls into three parts. In the first a comparison is made of the volumes of water passing through plant tissue by osmosis with the volumes of water passing through the same kind of tissue when pressure or suction is applied. The tissue was used in the form of membranes consisting of segments of the petiole of *Carica papaya*. It was found that the rate of movement of water by osmosis through such a membrane is very much slower than that which obtains when the same pressure is exerted mechanically. The author of the paper thinks it doubtful whether an actively transpiring plant could absorb enough water by the ordinary osmotic process to replace that lost by transpiration. The second part of the work concerns the part played by living cells of the root in the absorption of water by actively transpiring plants. To investigate this question comparison was made of the volumes of water exuding from cut stems of a number of different plants with and without the application of suction. It was found that under reduced pressure effected by the use of a vacuum pump the amount of water exuding from cut stems increased in the cases examined by from 153 to 575 per cent. Killing the root system brought about a further increase in the amount exuded under suction, the increases observed varying from 84 to 1,790 per cent. It was also found that plants with killed root systems could absorb as much, or more, water to replace that lost by transpiration than the same roots before they were killed. The third part of the work deals with the part played by the living cells of the root in the development of root pressure. In this connection it was found that immersing the root system in a sucrose solution with an osmotic pressure of one atmosphere suppressed the exudation of water. Sunflower plants with intact shoot systems remain unwilted in such solutions. This shows that water is absorbed by intact plants under conditions where decapitated plants do not absorb water. This supports the idea that the complex of forces concerned in the absorption of water by plants in which little transpiration is taking place differs from that concerned in water absorption by an actively transpiring plant.

W. Berger ("Das Wasserleitungssystem von krautigen Pflanzen, Zwergsträuchern und Lianen in quantitativer Betrachtung," *Beih. z. bot. Centralbl.*, Abt. 1, **48**, 363–90, 1931) has measured the specific conductivity of the wood of a number of plants and compared the values so obtained with the theoretical ones calculated from Poiseulle's formula. He finds in lianes the actual values obtained empirically correspond with

those obtained by calculation from the formula, whereas in shrubs and herbaceous plants the measured values were found to be only 12 to 22 per cent. of the calculated values. Miss N. M. Blaikley ("Absorption and Conduction of Water and Transpiration in *Polytrichum commune*," *Ann. Bot.*, **46**, 289–300, 1932) has made an investigation of the ascent of water in the moss *Polytrichum*. She concludes that in *P. commune* there is a high rate of internal conduction of water, the central strand playing an important part in the conduction of water in this moss.

An investigation of the influence of light and saturation-deficit of the atmosphere on the transpiration of different types of leaves has been made by G. Mittmeyer ("Studien über die Abhängigkeit der Transpiration verschiedener Blatt typen vom Licht und Sattigungsdefizit der Luft," *Jahrb. f. wiss. Bot.*, **74**, 364–428, 1931). Three types of leaves were considered: the "hard-leaf" type, represented by *Hedera helix*, *Rhododendron ponticum*, and *Laurus nobilis*; the "soft-leaf" type, represented by *Melissa officinalis*, *Asarum europæum*, and *Syringa vulgaris*; and the "delicate-leaf" type, represented by *Impatiens parviflora*. Under conditions of strong insolation and optimal water-content the soft and delicate types of leaf transpire more strongly than leaves of the hard type. Transpiration through the cuticle was examined by covering the under surface of the leaves with cocoa-butter. This method can, however, give only dubious results, for in the case of *Melissa* values for cuticular transpiration obtained in this way were found up to twice that of the total transpiration, while even with the hard-leaf type the cuticular component gave values up to 75 per cent. of the total transpiration. In *Rhododendron* sun leaves were found to have stronger cuticular transpiration than shade leaves. Insolation has a strong effect in furthering cuticular transpiration, particularly in the case of leaves of the hard type. The author concludes that light is the determining factor in evaporation from xerophytes, but his results also show that saturation deficit has some effect.

Some further work on transpiration has been published by A. R. C. Haas and F. F. Halma ("Relative Transpiration Rates in Citrus Leaves," *Bot. Gaz.*, **93**, 466–73, 1932). The observations were made on three species of *Citrus* of economic importance, namely, eureka lemon (*C. limonia*), marsh grape-fruit (*C. grandis*), and Valencia orange (*C. sinensis*). Among these species transpiration was most rapid in the lemon, slower in the grape-fruit, and slowest in the orange. Transpiration was more rapid from the lower than the upper surface, from twice to 3·5 times as much water being lost from the former as from the latter.

Among numerous papers published during recent years

dealing with the water relations of plants mainly from an ecological standpoint, passing reference may be made to the following: "Untersuchungen über den Wasserhaushalt der Hochmoorpflanzen," by F. Firbas (*Jahrb. f. wiss. Bot.*, **74**, 459–696, 1931), in which moorland plants such as *Calluna vulgaris*, *Empetrum nigrum*, and *Vacciniun uliginosum* are considered; "Transpiration und Wasserhaushalt in verschiedenen Klimazonen," by O. Stocker (*Jahrb. f. wiss. Bot.*, **75**, 494–549, 1931), which deals with the vegetation at the tree limit in Swedish Lappland; "Untersuchungen über die Anatomie und Wasserökologie einiger Ostseestrandpflanzen," by W. Hüser (*Planta*, **11**, 485–508, 1930), in which halophytes and the problem of their succulence are considered; and "Über den Wasserhaushalt von Pflanzen der Sandwüste im südöstlichen Kara-Kum," by I. M. Vassiljev (*Planta*, **14**, 225–309, 1931), which deals with the question of water relations of plants of the sandy deserts of Central Asia.

Next, reference may be made to a paper by the late Prof. R. H. Yapp and Mrs. U. C. Mason ("The Distribution of Water in the Shoots of Certain Herbaceous Plants," *Ann. Bot.*, **45**, 160–81, 1931). Observations were made principally with plants of *Helianthus annuus* and *Vicia faba*. The chief conclusions drawn with regard to the water-content of leaves of these species are as follows. Under ordinary conditions, and so long as the oldest leaves have not passed their period of greatest activity and new leaves are still developing, the maximum water-content is in the lowest foliage leaf, and, indeed, in the case of *Helianthus*, in the cotyledons. As one proceeds up the stem the water-content of the leaves is successively less, the minimum being reached in certain young leaves, but not in the youngest, for the still younger leaves of the apical region show a regular increase in water-content with a secondary maximum in the apical bud. As a plant increases in age the average water-content of the leaves decreases, and as the oldest leaves die the positions of the maximum and minimum become less definite. The greatest range of water-content is found at the same stage of development as the minimal water-content; this is found in *Helianthus* in leaves which have expanded to about half their full size, while in *Vicia faba* both occur in leaves just separated from the terminal bud. These results suggest that the fluctuations in turgor are greater in such leaves than in those in some other stage of development. When conditions are such as to restore the water balance of a plant the greatest increase in water-content takes place in partly expanded leaves. It is therefore suggested that the partly expanded stage of the leaf is the critical one in leaf development as far as water relations are concerned.

Finally, notice may be taken of a paper by R. C. Malhotra (" A Contribution to the Physiology and Anatomy of Tracheæ with Special Reference to Fruit Trees. II. Water Conductivity in Higher Plants and its Relation to Tracheæ," *Ann. Bot.*, **46**, 11–28, 1932). The author had previously shown that a unit area of the lumina of plum wood is more efficient to conduct water than a similar unit area of the lumina of apple wood. He now finds that some other factors compensate for this efficiency of plum wood. Thus the sap extracted from plum wood appears to possess greater density and higher viscosity than sap extracted from apple tracheæ. It was also found that the walls of plum tracheæ offered 10·75 per cent. more resistance to the flow of either plum or apple sap than the walls of apple tracheæ, while the plum sap offered 15·65 per cent. more resistance on account of its nature. On account of these two factors alone the apple shows itself to be 26·4 per cent. more efficient in its conductivity than plum.

AGRICULTURAL PHYSIOLOGY. By John Hammond, M.A., School of Agriculture, Cambridge.

Milk Production.—(*a*) *Growth of the Udder.*—In a study of the developmental changes in the mammary gland of the rat by Turner and Schultz (*Missouri Agr. Exp. Sta.*, Res. Bull. 157, 1931), it was found that injection of œstrus hormone into castrated animals produced duct growth similar to the growth occurring from birth to puberty, that corpus luteum extract alone did not produce significant changes, but simultaneous injections of the two produced more growth than œstrus hormone alone, but in no case as much growth as that which occurs during pregnancy. The fœtal development of the mammary gland in cattle has been described by Turner (*Missouri Agr. Exp. Sta.*, Res. Bull. 160, 1931), and the subsequent development has been studied (*Missouri Agr. Exp. Sta.*, Res. Bull. 156, 1931) by the yield of secretion obtained from the nipples. Dairy calves rarely secrete " witches' milk " at birth, and it is not until puberty that, in many cases, small amounts of secretion are produced, which increase during or following œstrum ; during the first pregnancy the secretion remains at the same level, or declines until the last twenty days of pregnancy, when there is a striking increase in milk secretion. He is careful to state that the yield does not measure the growth of secretory tissue, but only the stimulus to lactation. Fellner (*Klinische Wochensch.*, **10**, June 1931) finds that in rabbits and guinea-pigs œstrin coming from the corpus luteum and then chiefly from the placenta causes hypertrophy of the glands, and that with the removal of the placenta as a source of œstrin, milk secretion begins. Corner (*Amer. Jour. Phys.*, **95**, 1930) injected spayed

rabbits with corpus luteum extract, but could not cause proliferation of the mammary gland beyond the stage normally obtained at puberty; by administration of whole sheep's hypophysis, however, he was able to produce in two weeks a condition scarcely distinguishable from that present at the full term of gestation. Turner (*Missouri Agr. Exp. Sta.*, Res. Bull. 158, 1931) injected alkaline anterior pituitary extract into castrated rabbits whose glands had been previously developed, and even in extremely involuted glands lactation resulted following injection of the extract; the active principle appears to cause only activation of the secretory cells. Asdell (*Amer. Jour. Phys.*, **100**, 1932), by injection of anterior pituitary extract into lactating goats, has delayed the fall off in rate of milk secretion which occurs with advance in lactation. Alquier and de Sacy (*Le Lait*, **11**, No. 105, 1931) have shown that the rate of decline of milk secretion with advance in lactation in cows is also delayed by castration. In a book recently published Křiženecký (*Bisherige erfahrungen über den einfluss der inneren Sekretion auf ernährung und Stoffwechsel der Landwirtschaftlichen Nutztiere*, Berlin, 1932) has given an excellent account of the ways in which the glands of internal secretion affect animal production, and has included a long list of references to the scattered literature: it should form a most useful basis for those entering this promising field of investigation.

(*b*) *The Mode of Milk Secretion.*—By the use of a manometer the milk pressure in the udder has been recorded before and during the milking of one quarter in a number of cows by Krzywanek and Brüggemann (*Milchwirt. Forsch.*, **10**, 1930; **11**, 1931); from the pressure curves obtained they conclude, contrary to Filipovic's results, that all or almost all the milk obtained from the udder during milking is already present in the udder, and that the act of milking does not cause increased secretion. That milk pressure is an important factor in determining yield is shown by an investigation on the influence of the number of milkings per day on production undertaken at the University of Nebraska by Morgan and Davis (*American Guernsey Breeders' Journal*, **41**, No. 7, 1932); Holsteins milked twice a day yielded 9,563 lb. milk and 323 lb. fat, while with four times a day milking the yields increased to 20,130 lb. milk and 733 lb. fat.

(*c*) *Factors affecting Yield.*—The accuracy of milk records taken at different intervals of time has been investigated by Breirem (*Norges handbrukshøiskole*, 9th Stipendiatarbeide, 1931); he finds that in testing one day a month there is a 2–3 per cent. standard deviation, with 6 per cent. as the greatest deviation, provided the test is made in the middle of the period concerned. Johansson (*Kungl. Lantbruksakad. Handl. och Tidskrift*, H. 1,

1930) finds that the age at first calving has very little effect on the lifetime yields of butter fat, although those which calved late suffered most from irregular breeding afterwards.

A number of papers at the World's Dairy Congress, Copenhagen, 1931, provide a good account of the factors affecting yields; Zwagerman shows that the milk yield is affected much more than the butter-fat yield by environmental conditions; Østergaard, in an account of the factors affecting yield in Danish cows, finds that the maximum daily yield occurs about 30 to 40 days after calving; and Tuff describes the effects of age and month of calving. In a book on milk production, Elpatievsky (*Institute of Agriculture, Saratov, U.S.S.R.*, 1932) has compiled an account of the factors affecting milk yields which have been derived from statistical evidence, and he includes a large number of references to the literature. Schmidt, Lauprecht, and Stegen (*Landw. Jahrb.*, Berlin, 1930, p. 933) investigated the records of cows entered in the German advanced registry herdbook; from the 3rd to the 5th and subsequent lactations, the yearly milk yield varied from 7,600 to 9,200 kg., the butter fat from 278 to 344 kg., while the percentage of fat on the other hand remained fairly constant throughout. Yields according to the month of calving were also investigated, and it was also found that the higher the amount of digestible protein in the food the higher was the yield of milk.

(*d*) *Feeding.*—An account of recent experiments in animal nutrition is given in a book by Dmitrochenko and Sletoba (*Principles of Nutrition in Farm Animals*, Moscow, 1931). A technic for studying lactation in small animals has been evolved by Kzlowska, McCay, and Maynard (*Jour. of Nutrition*, **5**, 1932), and the effects of high and low protein diets have been studied; a low protein diet of 10 per cent. casein to rats gave much inferior results to one at a 40 per cent. level. The requirements of feed units and proteins for milk production in cows has been the subject of a comprehensive investigation by Frederikson (136 *Ber. Forsøgslab., Vet-og Landbohojskole*, Copenhagen, 1931). Savage and Harrison (*World's Dairy Congress*, Copenhagen, 1931), in an experiment with cows, find no evidence of any stimulating effect of protein on milk secretion. By the addition of calcium carbonate and common salt to hay deficient in mineral content, Scheunert, Reschke, and Specht (*Die Tierernährung*, **2**, 1930) were able to prevent the fall in the rate of milk secretion in goats that otherwise occurred.

(*e*) *The Blood in Relation to Milk Secretion.*—Borissenko (*Institute of Dairy Farming, Molochnaia, Vologda, U.S.S.R.*, No. 92, 1931) finds, from an investigation of the potassium and calcium in the blood of dairy cattle, that the amount is affected by pregnancy, lactation, time of year, etc.; potassium and

calcium are antagonistic, and the potassium content of the blood falls as lactation advances, while the calcium correspondingly increases. Sjollema, Seekles, and van der Kaay (*Tijds. voor Diergeneeskunde*, **57**, 1931) find that injections of calcium gluconate and other organic calcium salts given to cows in cases of milk fever often cause local œdema. A dye injection method for the determination of blood and plasma volume in the living cow has been used by Turner and Herman (*Missouri Agr. Exp. Sta.*, Res. Bull. 159, 1931), and it was found that, whereas lactating cows have a blood mass of approximately 8·1 per cent. of body weight, in the non-lactating cow it is only 6·4 per cent. The blood composition, particularly as regards the differences between beef and milk types, is discussed in detail, together with many other facts of physiological interest, in a recent book on Cattle by Duerst (*Grundlagen der Rinderzucht*, Berlin, 1931). Maynard, Harrison, and McCay (*Jour. Biol. Chem.*, **92**, 1931) find that following parturition in cows there is a rapid rise of fatty acids, phospholipid fatty acids, and cholesterol in the blood, which drops again gradually to the original level when the succeeding dry period is reached. McCay and Maynard (*Jour. Biol. Chem.*, **92**, 1931) also conclude that cows which are secreting large quantities of milk and fat are unable to synthesise sufficient fat within their bodies to permit the maximum secretion by the mammary gland unless a liberal amount of fat is allowed in the ration.

(*f*) *Milk Composition.*—The *Proceedings of the World's Dairy Congress*, Copenhagen, 1931, contain a number of papers dealing with this subject: Brouwer, who discusses the effect of feeding, mentions the beneficial effects of feeding coco-nut and palmnut cake in raising the fat percentage of milk; he considers that this is due to these fats being more similar to animal fat than those of other oilcakes, rather than to any specific stimulus to fat production produced by them. Sheehy finds that, in the great majority of cases, feeding fat has no effect on the fat content of milk. Hansson shows that the hard consistency of butter obtained during the winter months is due to the effects of feeding during this period, for coco-nut and palmnut cakes, which have been fed largely on account of their raising the fat percentage of the milk, give too hard a fat; this can be counteracted, however, by feeding an equal amount of rape, sunflower, or linseed cake, which give a soft fat (see also Hansson and Olofsson, *Centralanstulten för försök, på jordbruk.*, Med. Nr. 394, Stockholm, 1931). A statistical analysis of the variability and the way in which the fat content in milk has been raised from an average of 3·3 per cent. in 1912 to 3·7 per cent. in 1927 in the Friesian Herdbook Society has been published by Overbosch and van der Plank (*Tijds. voor Diergeneeskunde*, **58**, 1931). A

comprehensive investigation of the colour of milk, which is so important commercially in these days of bottled milk, has been made by Thompson (*American Guernsey Breeders' Journal*, **40**, Nos. 10, 11, and 12, 1931); the colour, which is produced from the xanthophyll and carotin pigments of plants, is highest in October and November after the summer on grass and lowest in February and March after winter feeding. There is a wide variation among individuals of the Guernsey breed in their ability to utilise and store this pigment, and the ability remains constant not only over one but over all lactation periods. Breeds rank from highest to lowest in milk colour as follows: Guernsey, Jersey, Ayrshire, Friesian; every breed, however, has individuals testing higher than some Guernseys. In inheritance by crosses from different breeds the paler colour, although blending in inheritance, is slightly dominant.

(*g*) *Feeding Value of Milk.*—A comparison of the growth rates of different species of animals during the suckling period with the chemical composition of the mother's milk has been published by Belle (*Le Lait*, **11**, Nos. 105 and 106, 1931, and *Recherches sur la croissance de quelques mammiferes*, Lyon, 1930): a remarkably high degree of correlation is observed between the rate of growth and the content of proteins and of salts in the milk of different species. The great importance of the supply of milk, as being the chief limiting factor for growth in early life, has been shown for mice by MacDowell, Gates, and MacDowell (*Jour. Gen. Phys.*, **13**, 1930), and for sheep by Hammond (*Growth and Development of Mutton Qualities in the Sheep*, Edinburgh, 1932). The nature of the curd clot in the stomach has an important effect on the digestibility of milk, and this has been found by Hill (*Utah Agr. Exp. Sta.*, Bull. 227, 1931) to vary from one cow to another. Espe and Dye (*American Jour. Diseases of Children*, **43**, 1932) have found that a doubling of the curd tension of milk increases the length of the digestive period from 30 to 65 per cent.; the percentage of casein is the chief factor which influences curd tension and dilution with water decreases it. Sheehy (*Farmer's Gaz.*, **90**, 1931) has obtained very successful results in calf rearing by diluting the milk with water before feeding.

(*h*) *The Life of the Dairy Cow.*—Few cows die of old age: they usually fade away. It has been the purpose of a number of recent investigations to find out exactly the causes of wastage in the cow population, with the object of directing research to the main causes of loss to the industry. Results have been, and are being, obtained by various workers from the districts of West Sussex, Reading, Wales, Scotland, and East Anglia, and these have all much the same story to tell. Buchanan Smith and Robison (*Jour. Agr. Sci.*, **21**, 1931) find the annual replace-

ment figures to be 27 per cent. Sanders (*Rept. Agricultural Organisers Conference*, 1931) for East Anglia finds that the average length of life of a cow in one herd is only 4½ years; of those leaving the herd only 5 per cent. do so because of old age, the most important causes of disposal being sterility 25 per cent., low milk yield 19 per cent., tuberculosis 10 per cent., and udder troubles 5 per cent.

(*i*) *Inheritance of Milk Production.*—Much work has recently been done in attempting to find better methods for breeding dairy cattle, with a view to preventing the appearance of low yielders, thereby avoiding the expense incurred in rearing them to milking age, having reached which, they have to be culled. While selection can be made on the cows according to yield, it is generally recognised (see Hammond, *1930 Yearbook, Central Council of Milk Recording Societies*) that in most cases the bull has been selected on pedigree alone, without reference to progeny tests, and an attempt is now being made to obtain better methods for the selection of bulls. This breeding work is closely linked with physiology, for with a complex character such as milk secretion the environmental conditions have to be measured in order to appreciate properly the genetic value of a milk record. Many indices have been evolved to measure the milk-transmitting characters of a bull, and recently two independent workers have, by use of different methods, arrived at similar conclusions from a survey of these different indices. Both Gowen (*World's Dairy Congress*, Copenhagen, 1931) and Edwards (*Jour. Agr. Sci.*, **22**, 1932) find that the simple average of the mature corrected yields of the daughters gives results far superior to those obtained by the use of complicated formulæ. Edwards (*Cambridge Milk Recording Society Handbook*, 1930–31) has suggested a simple means by which Bull-Recording can be done by Milk Recording Societies. Studies of Danish Progeny tests by Larsen (*World's Dairy Congress*, Copenhagen, 1931) indicate that certain bull lines are highly homogeneous and others heterogeneous. Buchanan Smith and Robison (*World's Dairy Congress*, Copenhagen, 1931) suggest that certain of the factors affecting milk yield may be inherited in a sex-linked manner, and this has been supported by Madsen's (*Nature*, Jan. 30, 1932) investigation of Danish records.

(*j*) *Tropical Dairying.*—The World's Dairy Congress at Copenhagen last year included a special section for this subject, which is now to be given a permanent place in its activities. The difficulties of acclimitising European milk breeds in the tropics were dealt with, and special methods of feeding, breeding, and management were discussed. Edwards (*Jour. Dairy Research*, **3**, 1932), from data obtained in Jamaica, describes the degeneration that occurs in European cattle

reared under tropical conditions. He finds that cows containing from $\frac{1}{4}$ to $\frac{1}{8}$ of Zebu blood yield more milk than either pure European or pure Zebu cattle, in that the constitution to withstand the tropical climate and diseases inherited from the Zebu, when combined with the udder capacity of European breeds, gives them an advantage over both the parent types, which are lacking in one or other of these qualities.

PEDOLOGY. By Prof. N. M. Comber, D.Sc., A.R.C.S., F.I.C., The University, Leeds.

A number of new books which do much to consolidate Pedology as a subject and to widen interest in it have recently appeared. Prof. F. Schucht's *Grundzüge der Bodenkunde* is welcomed for its concision and for its broad appeal to botanists, geographers, and geologists, as well as soil students. *The Physical Properties of the Soil*, by Dr. B. A. Keen, is an invaluable account of more recently studied aspects of soil science; and, as vol. X of Zsigmondy's *Kolloidforschung in Einzeldarstellungen*, Dr. H. Gessner gives an excellent and up-to-date account of the theory and methods of mechanical analysis.

The most recent addition to the books on Pedology is Prof. G. W. Robinson's *Soils, their Origin, Constitution, and Classification: An Introduction to Pedology.* This is written essentially for those interested in the soil as an object of study in itself, and is the first real handbook of Pedology to appear in English. It is a unique contribution to the literature of the subject, and will be of the utmost value to soil students.

Exchangeable Bases and the Constitution of Clay—the SiO_2/R_2O_3 ratio.—In continuance of his studies of the Laws of Soil Colloidal Behaviour, Sante Mattson (*Soil Sci.*, 1931, **31**, 57, 311; **32**, 343) has studied certain synthetic and isoelectric precipitates, which are formed in a manner that is in essence comparable to that in which soil colloidal complexes are thought to be formed. Using humates, silicates, and phosphates, along with aluminium and ferric salts, he prepared phospho-humates, silico-humates, phospho-silicates, etc. Thus, for example, the alumino-humate precipitate is prepared by mixing standard sodium humate with standard aluminium chloride. The pH is adjusted to any required figure by adding hydrochloric acid to the chloride or sodium hydroxide to the humate. For any given ratio of sesquioxide to humate (or silicate) there is a definite pH at which the precipitate flocculates instantly and also shows no cataphoresis. This isoelectric precipitate has a higher ratio of humic acid (or silicic acid) to sesquioxide the lower the pH figure.

With the higher ratios of SiO_2/R_2O_3, cation exchange capacity (at $pH = 7$) is more pronounced, and with the lowest

ratios anion exchange is observed, although varying states of flocculation and other factors prevent the exchange capacity from being a linear function of the ratio. Quantitatively, this was found also to be true of soils with varying SiO_2/R_2O_3 ratios. The amphoteric behaviour of soil clay is not a new conception, but its general acceptance has unquestionably been deterred by the experimental fact that soil clays exhibiting anion exchange, if they exist at all, are both rare and localised. Mattson's work goes a long way towards justifying the conception on the evidence of facts. The view is put forward to explain the facts that the "acidoid" part of the clay (viz. the humus, silica, etc. is in partial combination with the sesquioxide and the free acidoid valencies are responsible for cation exchange.

The Optical Properties of Clay.—Marshall (loc. cit.) has developed the study of the optical properties of colloidal clay particles. When placed in a strong electric field caused by an alternating current, the particles in a suspension orientate themselves with the direction of greatest dielectric constant parallel to the lines of force. By using this fact Marshall was able to prove that the clay minerals show a marked double refraction.

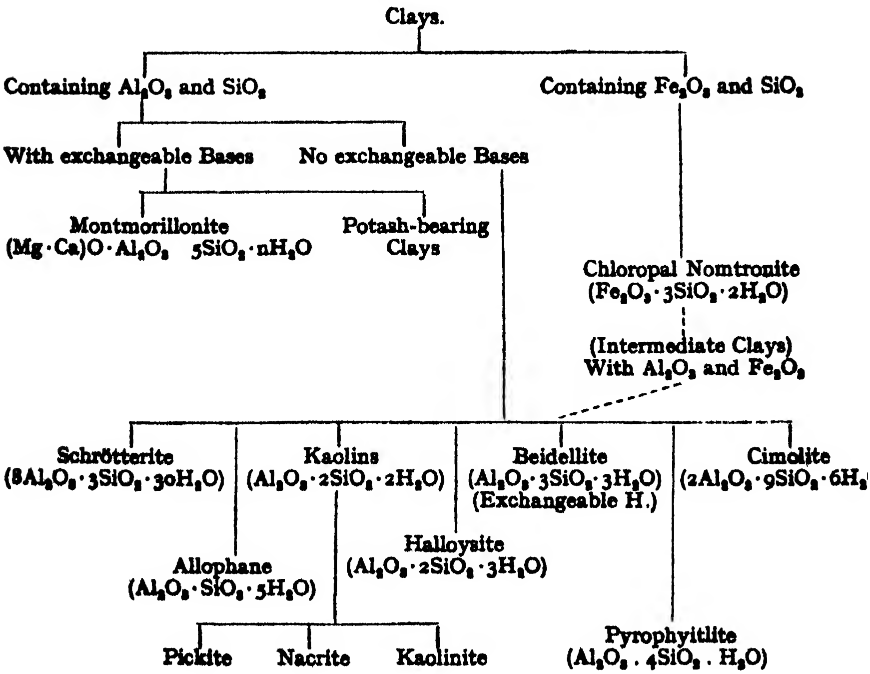
One of the most interesting and important observations in this work is that the hydrogen and alkaline earth clays have a much higher double refraction than the ammonium and alkali clays. It has long been known in a general way that the hydrogen and alkaline earth clays tend to be coagulated, while the ammonium and alkali clays are well dispersed. Since, therefore, these coagulated clays show a higher double refraction, the coagulation must be regular and orientated and not random.

Using his centrifuge method for the mechanical analysis of clays, Marshall (*J. Soc. Chem. Ind.*, 1931, **50**, 444 T) has studied the influence of different cations on the state of coagulation. This influence is found to be different with different types of clay. Their extreme sensitiveness and very small base exchange capacity make it difficult to draw conclusions about the Kaolins, but quite definitely the beidellite type of clay is very differently dispersed according to the exchangeable cation, while the state of dispersion of the Montmorillonite type is hardly affected by change of cation.

The Mineralogy of Clays.—There is now no doubt that soil clays are essentially crystalline, even although amorphous material may coexist with the crystals. X-ray work by Kelley, Dore, and Brown (*Soil Sci.*, 1931, **31**, 25) confirms the earlier conclusions of Hendricks and Fry on the crystallography of clay and the orderly arrangement of the exchangeable cations in a lattice structure. They further examined the effect of prolonged grinding in an appropriate ball mill on the exchangeable cations of bentonites and soil colloids. The bentonites

and the colloidal fractions of certain soils were, before being ground thoroughly, treated with a calcium salt to convert them into the calcium complexes. It was then found that after grinding the amount of exchangeable calcium remained the same, but large amounts of exchangeable magnesium were present in addition. The general conclusion is that the mineral involved in the soil colloids examined by Kelley, Dore, and Brown, and produced by weathering is of the Montmorillonite type $(MgCa)O,Al_2O_3 . 5SiO_2\, x\, H_2O$. It would appear likely that in the circumstances to which these products of weathering are placed, calcium, potassium, sodium, and hydrogen become prominent on the surface of the colloidal crystal particles, while the original magnesium remains preponderant within, and is brought into the sphere of action by grinding. Some exchangeable potassium is also released by grinding.

C. E. Marshall (*Trans. Far. Soc.*, 1931, **30**, 81) has put forward a tentative classification of the clay minerals as follows:



Exchangeable Bases and Field Conditions.—A. Evan Harris (*Soil Sci.*, 1931, **32**, 435) has studied the permeability of calcareous alkali soils (*i.e.* calcareous soils containing much replaceable sodium). It is found that the permeability varies inversely and exponentially with the sodium content. The

time factor in the reclamation of these alkali soils is discussed. E. M. Crowther and S. K. Basu (*J. Agric. Soc.*, 1931, **21**, 689) have examined the replaceable bases in the Woburn plots after fifty years' continuous cropping with cereals. During the fifty years the unmanured plot has lost about 50 per cent. of its original replaceable calcium (there was little, if any, free carbonate at the beginning of the period), the ammonium sulphate plot has lost more, and the sodium nitrate plot less.

Soil Organic Matter

The Artificial Oxidation of Soil Organic Matter.—The oxidation of soil organic matter in the laboratory is of twofold significance. It is necessary, as a practical preliminary to a mechanical analysis in order to disperse particles bound by humus, and the fractional oxidation of soil organic matter is calculated to throw some light on the constitution of that organic matter.

In the pretreatment of soil for mechanical analysis, boiling hydrogen peroxide has been used for the most part. The substitution of cold sodium hypobromite has been examined by Troell (*J. Agric. Sci.*, 1931, **21**, 476). He finds that in addition to such advantages as cheapness and greater stability in tropical temperatures, sodium hypobromite in place of hydrogen peroxide makes the additional treatment with acid, and the use of ammonia as a deflocculant, unnecessary. The sodium clay that is formed is, it is said, fully dispersed even in the presence of calcium carbonate. Moreover, the avoidance of acid and hot reagents reduces to a negligible amount the dissolution of the clay particles.

Prof. G. W. Robinson suggested some years ago that the organic matter oxidised by hydrogen peroxide might be regarded as the " humified " organic matter. W. O. Robinson of Washington threw doubt on this, and recently W. McLean, working in G. W. Robinson's laboratories, has published two papers on the matter (*J. Agric. Sci.*, 1931, **21**, 251 and 595). As the concentration of the hydrogen peroxide is increased up to 2–3 per cent., the C/N ratio of the material oxidised remains constant and the material is designated the " oxidisable complex." Thereafter non-nitrogenous matter only is oxidised, although nitrogenous organic bodies appear to be obdurate to the treatment. The oxidisable complex accounts for the majority of the organic matter, and evidence is brought forward to show that in soils of the same type the higher percentage of the oxidisable complex is found in the more fertile soils.

For purposes of analysis, it has for some time been assumed

that the percentage carbon in soil organic matter is 58 per cent., and that 1·724 may be taken as a conversion factor to determine the percentage organic matter. It is perhaps not surprising that this should be called in question. H. A. Lunt (*Soil Sci.*, 1931, **32**, 27) shows that, in the case of forest soils, at any rate, the stage of decomposition is an influential factor, and that in some soils the conversion factor may be as high as 1·9.

F. J. Salter (*Soil Sci.*, 1931, **31**, 413), in a study of the C/N ratio of soils, concludes that that ratio determines the micro-organic activities of the soil, no matter what the specific organic compounds present may be. A wide ratio of C/N appears to enhance the soil organic matter as a source of energy for nitrogen fixing organisms, but until the ratio is narrowed to about 10 : 1 the nitrogen remains in complex and comparatively unavailable form. The narrow ratio is most conducive to the formation of ammonia and nitrate from protein, while the wide ratio is most conducive to the formation of protein from "fixed" nitrogen.

METEOROLOGY. By E. V. Newnham, B.Sc., Meteorological Office, London.

Classification of the World's Climates.—The various attempts that have been made to classify the known climates of the world since their division by the ancients according to latitude simply into torrid, temperate, and frigid zones, have generally rested upon the observed tendency for the general character of natural vegetation to be controlled by climate. So long as one's observations are confined to a limited area, within which the range of climate is small or moderate, this may seem a hopeless task, for within such an area it would appear as though soil is far more important in governing the type of the vegetation. Thus Gilbert White, in his *Natural History of Selborne*, describes a variety of vegetational types within the limits of a single English parish, and takes it for granted that they depend upon the fact that the geological strata underlying them are different and have left their stamp upon the surface soil. Seeing how very slight are the differences of climate within that parish, and how close is the connection between the vegetation and the soil, he could hardly have done otherwise. Modern soil classification, which owes a great deal to researches made in Russia into the composition, the mode of origin, and the distribution of the different types of soil, leads to a very different view of these matters. When dealing with the different soils of the world very broad types have to be defined, each containing a considerable range of variation. Between such broad soil types and correspondingly broad types of climate that must be defined before the complicated mixture of the world's climates

can be reduced to some kind of order, relationships are found that give good grounds for the belief that in the long run the climatic factor outweighs the geological one in the process of soil-formation by weathering of rock. It has been shown that temperature and rainfall are the most important factors in deciding which substances are to remain in the soil and which are to be washed out by the process known as " leaching." In this way hot climates with a low rainfall tend to give rise to alkaline soils rich in mineral salts ; these are very characteristic of dry subtropical regions, where the problem of successful agriculture is often simply one of irrigation. In contrast to these are the soils of cold wet regions in high latitudes, which are usually acid, and contain comparatively small amounts of nutritive material, and in consequence need to be manured before they can be made to yield abundant crops.

If, therefore, climate not only decides what type of vegetation shall predominate for a given soil, but even has a large say in deciding what the general character of the soil shall be, the case for a classification related to vegetation appears to be strengthened, although one based on genetic relationships may be preferred by some on the grounds that it tends to a better understanding of the physics of climatology. But it must never be forgotten that the classification on the basis of vegetation can only be successful when the latter is dealt with on broad lines. Where the conditions most favourable for a particular plant change gradually to conditions that, if not actually unfavourable, are more suited to other plants that compete with it in the struggle for existence, the distribution of the plant in question in that region may be controlled largely by factors that have no direct connection with climate.

It is proposed now to pass on to a brief survey of one of the most up-to-date and painstaking attempts at such a classification, that of Köppen.[1] This is based primarily on temperature, rainfall, and the seasonal variation of these two elements. Before going into the precise specification of each of the eleven primary climatic divisions which form the basis of his system, it is proposed to give a general description of each, taking them roughly in the order in which they occur between the equator and the poles. Since their arrangement is to a large extent controlled by the prevailing wind systems (of great importance for rainfall) and by solar radiation (more important for temperature), and these to a great extent depend upon latitude, a more or less zonal arrangement would be expected, and is actually to be found, with certain distortions due to the varying proportions of land and sea.

[1] The most recent account of his system is his *Grundriss der Climakunde* (1931), published by W. de Gruyter & Co., Berlin and Leipzig.

Type Af.[1]—Within a few degrees of the equator there is a very definite zone of constantly high temperature with abundant rainfall at all seasons. The natural vegetation is a luxuriant forest, because these conditions enable trees to grow to a great size and so to rob almost all other plant forms of the light necessary for their growth. The Amazon forests provide a very good example of such a dense equatorial rain forest beneath which there is a kind of twilight during the daytime. It may be noted that abundance of rainfall at all seasons is a necessary condition for such forest development at the high temperature prevailing in that zone, because the rapid transpiration of water from the leaves of the trees must be supplied by the roots of the trees, and the ground would soon dry up if the ground water were not replaced.

Type Aw.—The existence of the large zone just described depends upon the fact that the seasonal displacement of the general circulation of the atmosphere in low and middle latitudes, due to varying declination of the sun, is not generally sufficient to allow places near to the equator to emerge for long into either of the trade-wind belts. If this were to happen there would normally be a relatively dry season. In type A*w*, however, this does take place, principally around latitudes 10° and 15° N. and S. Here the mean temperature is nearly, if not quite, as high as on the equator, and when the period of trade wind sets in and brings relatively dry weather the drying power of the air may be even greater than in the rain belt owing to the lower relative humidity and longer sunshine. The tropical rain forest would not be able to survive such a dry period ; in its place there is a type of vegetation known as savannah, which is a varying mixture of drought-resisting trees or scrub, and tall grasses which die down temporarily during the dry period.

Type BS.—Still farther from the equator, mostly around latitudes 15° to 40° N. and S., we come to a zone which the equatorial rain belt never reaches, and where the trade-wind generally predominates all the year round, except in so far as large areas of land may set up their own monsoon winds. Under these conditions the rainfall is governed very largely by geographical and orographical circumstances. High mountain ranges, especially those near the eastern margins of the continents and on islands, may cause much orographical rainfall, but on proceeding westwards across the continents rainfall generally diminishes and desert conditions may finally be attained. But before the desert is reached a zone (BS) is generally encountered

[1] Wherever the small letters *f*, *w*, and *s* are used these imply respectively rain at all seasons, a minimum of rain in winter, and a minimum of rain in summer.

which has a rainfall insufficient for maintaining savannah but sufficient for the special "steppe" vegetation, composed of smaller drought-resisting shrubs and grasses.

Type BW.—This is the desert type. The vegetation is scanty and composed only of those plants in which drought-resisting devices are carried to an extreme, or vegetation may be absent altogether if the rainfall is sufficiently small.

Types Cw, Cs, and Cf.—These types cover a large range of latitude, but on an average are farther from the equator than any of the types already described and extend much farther polewards. They are the temperate climates, distinguished from one another by the different types of seasonal variation of rainfall designated by the small letters. Type C*f* is by far the most extensive. The general level of temperature and its annual range are under the tempering influence of the ocean, while the activity of cyclonic depressions leads to rain at all seasons. Type C*s*, of which the Mediterranean region, the extreme south of South Africa, and parts of the south of Australia furnish examples, generally arises where rainfall is due to the cyclonic depressions of temperate latitudes and where these exert their influence practically only in winter. Type C*w* is more nearly related to A*w*, for it occurs most frequently where the tropical rain belt is displaced into rather higher latitudes owing to monsoonal development over a large land area. The characteristic types of vegetation for these three climates are: for C*f*, tall-stemmed deciduous forests; for C*w* and C*s*, evergreen scrub, of which the Corsican maquis is a good example.

Types Dw and Df.—These are peculiar to the northern hemisphere, where a sufficiently large land area may induce so great an annual variation of temperature that, although the winter is so cold that the ground is always snow-covered for several months, the summer is warm enough for the development of forests. It is the climate, broadly speaking, of Canada, Russia, and Siberia. D*f* gradually changes to D*w* when, on passing from Russia into Siberia, the increasing distance from the cyclonic activity of the North Atlantic sufficiently reduces the winter precipitation. In the case of D*w* the rainfall in summer is largely due to afternoon showers and thunderstorms.

Type ET.—In very high latitudes the warmth of the summer eventually becomes just insufficient for the growth of forest, but is sufficient for the maintenance of a special type of vegetation—the tundra—which is adapted to a very short and cool-growing season in a generally poor and acid soil which tends to be waterlogged when not frozen, owing to the presence of impervious frozen ground beneath the thawed superficial layer.

Type EF.—The last of the eleven main types is to be found

in yet higher latitudes and on certain high mountains, where the summer is so cold that there is practically no vegetation. It is taken to begin where the mean temperature of the warmest month is below the freezing-point.

Nothing has been said so far about the precise degree of aridity required to bring about the flora of the steppe and the desert. Any attempt at relating these characteristic flora simply to the mean annual rainfall soon shows that this cannot be done because, owing to the rapid increase of evaporation with rising temperature, the limits must be varied according to the latter, or better still, according to the drying power of the air. Unfortunately, measurements of the average drying power of the air depend very much on the method adopted, and are not uniform throughout the different countries. Köppen, therefore, has recourse to mean annual temperature, but with a further correction according to the seasonal distribution of the rain. The formulæ that he uses are purely empirical ; they are shown in the following table, in which t represents the annual mean temperature (° C.) :

UPPER LIMIT OF ANNUAL RAINFALL IN CM. IN TERMS OF THE ANNUAL MEAN TEMPERATURE (t° C.)

Type.	Seasonal Variation of Rainfall.	Upper Limit of Annual Rain (in cm.)
BS	Summer maximum	$2(t + 14)$
BS	No significant seasonal variation . . .	$2(t + 7)$
BS	Winter maximum	$2t$

and as the upper limit for BW, *i.e.* as the boundaries between BS and BW, half these quantities under similar circumstances of seasonal variation of rainfall.

To complete the definitions of the types in so far as these are conditioned by rainfall, it is necessary to lay down some rules in regard to the use of the small letters *f*, *s*, and *w* in conjunction with the large letters C and D. The following have been used :

C*s* : if the rainiest month of the cold season yields at least three times as much precipitation as the driest of the warm months (if the fall in the latter is greater than 3 cm. the type would be C*sf*).

[D*s* : does not occur.]

C*w* and D*w* : if the rainiest month of the warm season yields more than ten times as much rain as the rainiest of the cold months.

C*f* and D*f* : if the differences between the months are less than those set out above.

It is clear that a number of other factors modify to some extent the efficacy of a given quantity of rain, *e.g.* the intensity of fall, the temperature and humidity of the actual time when the rain is falling. The weakness of the rough method of allowing for evaporation that has been adopted is occasionally apparent when the distribution of vegetation for a given climatic type is considered. In the region of La Plata, for instance, the distribution of trees is not in accordance with the climatic type, apparently because of the small number of days among which the annual rainfall is distributed. This weakness of the system of classification can clearly only be removed at the present time by employing much more complicated definitions of the boundary conditions, but in the future it may be found possible to combine simplicity with the necessary precision by using the drying power of the air instead of temperature. It is proposed now to deal with those definitions of the eleven principal types which rest solely upon temperature and its seasonal variation, and as a matter of convenience to give figures obtained by Wagner showing the areas of the earth's surface occupied by the different types. In connection with temperature, in explanation of the apparently peculiar limits sometimes adopted, it may be pointed out that in cold climates the presence or absence of a warm growing season is more important than the amount of rain, while in hot climates rainfall takes a much more important place, heat being destructive of vegetation only indirectly through evaporation. The following are the exact definitions of the eleven main types :

A*f* : mean temperature of coldest month over 18° C. (64° F.) ; annual rain above the limit for BS, without significant seasonal variation.
A*w* : same as A*f*, but a dry season in the winter.
BS, BW : Conditioned by rainfall in accordance with the formulæ already given.
C*f*, C*w*, C*s* : Coldest month between 18° C. (64° F.) and − 3° C. (27° F.) and seasonal variation of rain as shown by small letter.
D*w*, D*f* : Coldest month under − 3° C. (27° F.) and warmest above 10° C. (50° F.), seasonal variation of rain as shown by small letter.
ET : warmest month under 10° C. (50° F.), but over 0° C. (32° F.).
EF : warmest month under 0° C. (32° F.).

The distribution by area in millions of square kilometres is as follows :

	On land.	Over the ocean.	Total.	Percentage.
Af . .	14·0	103·3	117·3	23·0
Aw . .	15·7	51·1	66·8	13·1
BS . .	21·2	12·9	34·1	6·7
BW . .	17·9	2·2	20·1	3·9
Cw . .	11·3	1·4	12·7	2·5
Cs . .	2·5	10·7	13·2	2·6
Cf . .	9·3	103·2	112·5	22·1
Df . .	24·5	5·3	29·8	5·8
Dw . .	7·2	0·7	7·9	1·5
ET . .	10·3	57·8	68·1	13·4
EF . .	15·0	12·5	27·5	5·4

It is difficult on a moderate-sized map to show more than these eleven principal types, for there are many parts of the world where even these few follow one another with inconvenient rapidity within what is a very small distance on the map. This is especially the case where the level of the ground changes quickly. But as a mere shorthand method of describing smaller differences of climate Köppen adds a number of small letters to which various meanings are attached. An example will make the method clear. In Central Africa there is a large area of steppe country (BS), most of which can be represented by BS*hw*, where *h* stands for mean annual temperature above 18° C. and *w* shows that there is a dry season in winter. In the south of Russia there is also steppe country, but of a different kind, which can be represented by BS*kx*. Here *k* shows that the winter is comparatively cold (annual mean under 18° C. but warmest month above 18° C.), and *x* shows that the rainiest season is the early part of the summer, while the late summer is fine and sunny.

Köppen's classification is the best known and probably the one most often used in investigations into the agricultural possibilities of different parts of the world. As there is no English translation of this work, English workers who cannot easily read German may have recourse to an English climatology[1] which contains a complete classification on somewhat similar lines to Köppen's. Seven principal types are employed, lettered A to G, namely, Hot, Warm-Temperate or Sub-tropical, Cool Temperate, Cold, Arctic, Desert, and Mountain. It is in some respects simpler, but the simplicity has been attained at some sacrifice of effectiveness. Desert climates are taken to be those with annual mean rainfall of less than 10 inches simply. This gives a general world distribution that does not differ greatly from Köppen's. There is no very obvious advantage of one system over the other, and it seems a pity that the com-

[1] *Climatology*, by A. Austin Miller, Methuen & Co., Ltd., London (1931).

parison between investigations based on climatic types made in English-speaking countries and those made in Germany should be complicated by the use of more than one system of notation. Miller's classification, it may be noted, is not based so much upon vegetation as is Köppen's; most of the sub-divisions of the main types are based on the seasonal variation of rainfall as controlled by varying monsoon effects related to the distribution of land and water. This lends itself better to a symmetrical and easily understandable notation.

ARCHÆOLOGY. By E. N. FALLAIZE, Royal Anthropological Institute, London.

International Congress of Prehistoric and Protohistoric Sciences.—Among the major events in the current archæological year must be counted the first International Congress of Prehistoric and Protohistoric Sciences, which met in London from August 1 to 6—not only because it is the first international congress in archæology to meet in England since 1868, but also because it was the outcome of a prolonged and difficult course of negotiations initiated by the Royal Anthropological Institute to revive, on a really international basis, the old International Congress of Prehistoric Archæology and Anthropology which met last at Geneva in 1912. The newly instituted congress is less comprehensive than the old, for, wisely as the event has shown, it restricts its field exclusively to topics which come within the scope of prehistory and the period of the earlier historic races. In the recent Congress the age of the Vikings marked the upward limit.

One feature in the communications presented to the Congress is to be marked, especially in contrast with those of the congresses which preceded the war. This is the far wider range now covered by archæological studies and the interrelation in synthesis of evidence drawn from widely separated areas. This was perhaps most evident in those sections of the Congress which covered palæanthropology and the earlier phases of prehistoric archæology, in which Palestine, Egypt, Mesopotamia, East Africa, China, and Java were laid under contribution.

Obviously little profit would accrue from an attempt to survey here the proceedings of the Congress as a whole, since they included communications only just under 200 in number. Mention can be made of one or two only of the topics of more immediate interest.

Peking Man.—The Abbé Breuil's account of the cultural evidence from the cave of Chou Kou Tien, the home of Peking man, which was accompanied by an exhibit of artefacts, was welcomed as affording an opportunity for judging at first hand the evidence for the inferences as to the stage of cultural

advancement attained by this primitive type of humanity. Sketches of the implements had already been published by Prof. Elliot Smith in *Man* for April and had elicited some critical comments from Mr. Reid Moir. The qualities of the material from which the implements are made, mainly, quartz, renders any conclusive verdict a matter of some difficulty, although the fact has to be recognised that the specimens which the Abbé could bring away from China were chosen from among the less distinctive. The Abbé pointed to the existence of hearths and charcoal at different levels as evidence of the occupation of the cave over some period of time, for which no human skeletal remains had been found to account, other than those of Sinanthropus. One remarkable exhibit, regarded by the Abbé as a cup, of horn, deserves more attention than it has received. The evidence of traces of fire on the implements shown elicited from Sir Arthur Woodward, who was in the chair, evidence for the early use of fire in Britain in the form of a flint implement from the Piltdown gravels, which he believed, from its size and shape, to have been used for heating water in a vessel.

Prof. Elliot Smith's communication on " New Discoveries in Human Palæontology " also touched on Sinanthropus. Superimposed cross-sections of the Piltdown and Peking skulls brought out the similarity in form of the two. They also emphasised the small size of the Peking skull—its capacity is only 900 c.c., practically the same as that of Pithecanthropus. The author also called attention to certain characters in the Piltdown skull by which, in fact, he said, morphologists should be convinced that the cranium of Piltdown man was at least as pithecoid as the jaw. It is perhaps worth while to mention here that it has recently been announced that other parts of the skeleton of Sinanthropus have been discovered, among them bones of hands and feet—an ungual phalanx (foot), a clavicle, and a semilunar bone (wrist). The hand is said to be completely human, the foot to show simian characters. The announcement was delayed in the hope of further discoveries.

Java Man.—The chief interest in Prof. Elliot Smith's communication, however, lay not in Peking Man, but in two other announcements relating to early man which he had to make. Of these the first was that he had been requested by Dr. E. Dubois, the discoverer of *Pithecanthropus erectus*, to announce that he had discovered in the course of last month three human femora among the material which he had brought with him from Java in 1900. These femora present the same peculiarities as the femur of Pithecanthropus discovered at Trinil in 1892, and, in Dr. Dubois' opinion, disposes of the possibility that the features of the original Trinil femur were due to individual

peculiarity. The association of the four femora, he holds, corroborate his view that they belong to this genus, while their form is a new justification of the specific name *erectus*. Prof. Elliot Smith also referred to the recent discovery of a hitherto unknown type of man at Ngandong in Java. Members of the Dutch Geological Survey have discovered five skulls in the Upper Pleistocene beds of the Solo River, some twenty miles from Trinil. In the original account of the discovery, which appeared in the records of the Survey, published at Batavia, and of which a brief résumé appeared in *Nature* of June 11, Mr. Oppenoorth gave his reasons for regarding *Homo soloensis*, as it is proposed to call it, a new type, resembling, yet differing from, Neanderthal man, presenting certain affinities with Rhodesian man, and ancestral to the modern Australian. Commenting on the description of Solo Man Dr. Dubois stated, in a letter to *Nature* of July 2, that he regarded the type as identical with that of Wadjak man, which he himself had discovered in 1889–90, and further emphasised the resemblance to Rhodesian man, bringing the latter more closely into association with the line of descent of the modern Australian, and possibly designating him as the prototype of *Homo sapiens*. Prof. Elliot Smith, in referring to this discovery at Ngandong, pointed out how it complicated the issue in regard to the new femora discovered by Dr. Dubois by suggesting that they might belong to *Homo soloensis*.

Lloyd's Skull.—The second pronouncement made by Prof. Elliot Smith related to the skull found in 1925 in the course of the excavations for the foundations of Lloyds new building in Leadenhall Street, London. The skull, or rather the fragments which have been restored to form part of a skull, was found at a depth of 42 feet from the surface. It belonged to a woman of about fifty years of age who probably was left-handed. It was derived from blue clay, which could be referred to the Flood Plain Terrace then assumed to be post-Mousterian in age. It presented such a profound contrast to post-Mousterian skulls hitherto occurring in Europe, that it was found difficult, if it were Aurignacian in age, to interpret its significance. Later, however, Mr. Broomhead expressed the view that the fluviatile beds which underlie Leadenhall Street are part of the Taplow or Middle Terrace of the Thames, and Miss Dorothy Garrod, on examining the evidence, has arrived at the conclusion that the skull is definitely Mousterian or, possibly, even earlier. Further, Dr. Matthew Young has compared the skull with a series of mediæval female skulls from Glasgow, which present the same peculiarity as the Lloyd's skull (the presence of a supra-occipital bone), and has expressed the opinion that the Lloyd's skull is not significantly different from that of *Homo*

sapiens, modern man. Owing to the fragmentary condition of the skull, certainty is not possible ; but there is a high degree of probability that it is vastly more ancient than any other known representative of the species.

Oldoway Man.—Prof. Elliot Smith was in a position to regard this as the oldest specimen of *Homo sapiens* with the more confidence in view of the fact that, as he put it, reasons had been advanced for " discrediting the claims for the remote antiquity of the Oldoway skeleton." It had been announced at an earlier stage in the Congress that the antiquity of Oldoway man had been disproved, but that the evidence upon which this conclusion was based was not yet available, although publication was imminent. The importance of recent controversy on the antiquity of the Oldoway skeleton will extenuate further digression. It will be remembered that in the course of last year Dr. Hans Reck, who discovered the Oldoway skeleton in Tanganyika in 1913, gave an account of his discovery before the Royal Anthropological Institute, and, as a result of the discussion which then arose, it was arranged that he should accompany Dr. L. S. B. Leakey, and Mr. A. T. Hopwood, of the British Museum (Natural History), to East Africa, and there examine afresh the stratigraphical evidence for the high antiquity of this specimen which, it was agreed, belonged to the type of *Homo sapiens*. Briefly, the finding of the expedition was that the human remains were contemporary with the beds in which they were found—the second from the bottom in a series of five. Comparison with the stratification of Dr. Leakey's discoveries in Kenya warranted an attribution of the remains to a Middle Pleistocene dating, while the five beds showed implements in a progression ascending from pre-Chellean to Acheulean and Aurignacian ; the second bed, in which were the remains, belonging to a Chellean horizon (*Nature*, October 24 and December 26, and *Man*, August 1932). An antiquity so remarkable for *Homo sapiens* was not accepted without question. French anthropologists, notably M. Marcellin Boule, and M. R. Vaufrey in *L'Anthropologie*, vol. XLII, Nos. 1–2, had felt some doubts on the grounds of the resemblance of the skeletal remains to the modern Masai ; while Messrs. Foster-Cooper and D. M. S. Watson had pointed out that the flexed position and the fully articulated skeleton, a condition virtually never found by the palæontologist in such deposits as these, suggested both a burial and a recent origin (see *Nature*, February 27, 1932). In reply Dr. Leakey admitted the probability of a burial, but reaffirmed its antiquity on the ground that neither the skeleton itself, which he had examined in Germany, nor the site showed any signs of intrusive material from the upper beds, as would inevitably have been the case, and as it would have been easy to detect, on account

of the differences in colour of the beds, had the burial been historic and of a later date than the laying down of Bed 2 (see *Nature*, May 22, 1932).

The final phase of the controversy was reached with the publication of a letter from Prof. P. H. G. Boswell in *Nature* of August 13, in which he stated that material taken from within the ribs of the Oldoway skeleton had been analysed and compared with an analysis of material from the beds overlying Bed No. 2 at Oldoway. The material from the Oldoway skeleton proved to be identical with material from Beds Nos. 3, 4, and 5. This evidence of the modern origin of Oldoway man is conclusive.

Palestine Man.—To return to the proceedings of the International Congress. Mr. Theodore McCown, of the American School of Prehistoric Research, and Sir Arthur Keith, gave between them an account of the recent discoveries relating to palæolithic man in Palestine and the deductions to be drawn therefrom. Mr. McCown described the discovery of the cemetery on Mount Carmel, which was announced in May last. It is situated in a small cave-rock shelter known as the Cave of the Kids (Mugharet es Sukhul), about fifteen miles south of Haifa, and one of the group of caves which is being excavated under the direction of Miss Dorothy Garrod by the joint Expedition of the British School of Archæology in Palestine and the American School of Prehistoric Research. The deposits of the cave consist of a hard bone breccia, with an abundant flint industry, which is a well-developed form of Levalloisian—a flake industry, the predominant form being Levallois, with the associated tortoise cores, but with a fair proportion of long narrow flakes that are properly classifiable as blades, burins of various types, and a number of crude angle gravers on Mousterian flakes with faceted butt. The deposits average a thickness of 3 metres, of which the top is soft, and contains a small number of Upper Palæolithic forms. Below this "surface film," the deposits become progressively harder, and are Mousterian throughout. The skull and skeleton of an infant were discovered here in 1931. This year eight more individuals were uncovered, seven in the hard breccia, and one, though unmistakably of the same breed, in softer material just above. All lie at depths of 1·5 to 2·5 metres, some actually on the floor, which is irregular. Two have now been completely cleaned. Such observations as could be made in the time indicate that these people combined Neanderthaloid features with others that are clearly Neanthropic. The skulls are high, with a well-vaulted frontal rising away from a tremendous supra-orbital torus, well-marked parietal eminences, and temporals with a heavy ridge running back towards a well-marked occipital torus. Facial and

alveolar prognathism is marked, and there is a massive jaw with rami set at nearly right angles to it and an unmistakable chin. The lower part of the face must have been exaggeratedly grotesque. The limbs are long and massive, with marked development of the surface for muscular attachments. A curved femur and retroversion of the tibia indicate a slouching gait.

Sir Arthur Keith added further particulars. He recalled that the earlier discoveries of a primitive type of man in Palestine—a skull, or parts of a skull, by Mr. Turville-Petre in Galilee in 1925 and teeth found by Miss Garrod at Shukbah and on Mount Carmel—showed Neanderthal characteristics; but the first discovery to reveal that we were dealing with a Neanderthal man that was not the European species was the discovery, also made by Miss Garrod, in 1931, of the complete skeleton of a child some 2½ years old. The skull of this child has a cephalic index of 72 and a capacity of about 1,000 c.c. The hinder half of the skull, while it has certain peculiar features, shows modern or neanthropic characters, the parietal eminences being pronounced, while the conceptacula for the cerebellar lobes are prominent and set widely apart. The tympanic plate differs from that of a Neanderthal child, and also from that of Sinanthropus; but it has resemblances to that of a modern child. The bones of the limbs in their absolute dimensions, as well as in their relative proportions, have close resemblances to those of Australian aborigines, the tibia being relatively long. The pelvis and hip joint show peculiar features. The teeth are not markedly taurodont, and their cusp pattern resembles that of Neanderthal man. Taking into account the combination of Neanderthaloid and Neanthropic characters, Sir Arthur regards this as a new type, for which he suggests the name *Homo palestinus*.

In a further communication Sir Arthur Keith dealt with the late palæolithic (or mesolithic) people of Palestine, who were discovered by Miss Garrod in association with a new mesolithic culture, to which she proposes to give the name "Natufian," from the name of the wady in which one of the excavated sites was situated. These human remains were obtained from caves situated at Shukbah in the Judæan Hills in 1928 and in caves on Mount Carmel in 1929, 1930, and 1931. Sir Arthur accepts the name "Natufian" to designate the people as well as the culture, for they are a peculiar people not to be identified with any living race, but perhaps to be assigned to that which is represented by the Mediterranean Race. They exhibit affinities with the neolithic inhabitants of Malta, the negroid element of Europe in Aurignacian times and, more distantly, the pre-dynastic inhabitants of Egypt and late palæolithic people of North Africa. At Shukbah remains representative of 45 indi-

viduals were found. Of these 25 were adult, 9 females and 16 females, while 3 were indeterminate. On Mt. Carmel a veritable cemetery contained remains belonging to 87 individuals. Of these 35 were adult males and 23 adult females, 6 being indeterminate. The number of complete skulls or skeletons is small. In only 20 individuals can an approximate size be given for the skull, while as regards shape, allowance has to be made for distortion due to pressure. However, it is possible to say definitely that the Natufians were a dolichocephalic people, the cephalic index varying from 72 to 78; that they had cap-shaped occiputs; that the dimensions of their heads was greater than those of the predynastic Egyptians; that their faces were short and wide, that they were prognathous, and that their nasal bones formed a wide, low arch. Their chins were not prominent, but were masked by the fullness of the teeth-bearing parts of the jaw. The stature was low—about 1·650 m. for men and 1·524 m. for women. There is a strong development of the bones of the thigh and leg in contrast to that of the arm, forearm, and shoulder.

From this material Sir Arthur drew some interesting inferences in regard to the cultural habits of the Natufians. It is noted that it was their custom to extract the two upper central incisors of the women. Of five palates from Shukbah, three show this mutilation. In the Mt. Carmel cemetery seven palates, all of women, show evidence of the extraction of one or both upper incisors. At Kebara, between Carmel and Shukbah, Mr. Turville-Petre found evidence of the same practice. The Natufians at Shukbah seem also to have practised cannibalism. This at least would appear to be the only explanation of the fact that the bones show evidence of having been cut and fractured when they were quite fresh. No such evidence appeared at Carmel or Kebara. A third practice of a still more remarkable character came to light at Kebara. In the mesolithic deposits were found an assortment of fragmented bones which had been burned—not when they were fresh, but after they had been freed from animal matter by exposure or burial. The fragments represent at least 75 individuals, mostly women. At the same time Sir Arthur had received from Mr. Leonard Woolley a box of human remains from under the foundations of Ur, which also represented, not ordinary cremation, but the cremation of dried skeletons. Again, women's bones preponderated. Miss Caton-Thompson had forwarded burnt bones from Zimbabwe, skulls of two women, which had been burned long after the flesh had disappeared from them. Was there, asked Sir Arthur, once a custom in ancient times of digging up the bones of ancestors and the submitting them to the ordeal of fire?

Dental Mutilation.—This reference to the cultural habits of the Natufians aroused comment from Prof. Elliot Smith on the ground of chronology ; and here we may refer to a letter from him which appears in *Man* for August. He there criticises certain cultural arguments which had been put forward as supporting the high antiquity of Oldoway man. One of these is the practice of dental deformation. The lower incisors of Oldoway man had been filed on the frontal aspect; and it had been maintained that this practice had not been observed elsewhere in Africa. Prof. Elliot Smith argues that the practice of dental deformation or mutilation was not introduced before about 300 B.C., his evidence being observations made by himself and Dr. D. E. Derry in a Ptolemaic-Roman cemetery in Lower Nubia in the neighbourhood of Dacca. A variety of dental mutilations was there recorded, and it is his opinion that the custom of filing, such as that observed in Oldoway, was the original method of ceremonial extraction of the teeth, and that it had almost immediately been superseded by lateral filing or evulsion.

The argument is of considerable interest, especially in view of two other recent studies of fossil man, in both of which evidence is shown for the practice of dental mutilation.

Fossil Types in Africa.—Of these, one was a communication made to the International Congress by MM. Marcellin Boule and H. Vallois dealing with "The Fossil Men of Afalou-bou-Rhummel (Algeria)," an investigation of which the archæological world is glad to have further details. The remains belong to at least 50 individuals, from which 9 skeletons up to now have been reconstructed. The skulls are described as almost all having a brutal aspect. The supra-orbital arches are united in a well-developed prominence at the glabella. Of 38 skulls, 16 are dolichocephalic, 16 mesaticephalic, and 5 slightly brachycephalic. The occiput sometimes tends to be chignon-shaped. The limb bones are stout. The type agrees with one already discovered in Algeria in deposits which are usually regarded as of Neolithic Age. It cannot be related to Neanderthal man, nor to Cro-Magnon, nor to the Mediterranean or negro types of modern times. It represents a new type of fossil man for which the name of the Mechta race is suggested. It is characteristic of the Capsian culture of North Africa. This people practised knocking out the incisor teeth in early life.

The second study, also by MM. Boule and Vallois, deals with a skeleton found near Asselar, a French post in the Sudan. The skeleton was found in 1927, but has only recently been partially cleared from its matrix, and studied by the authors, who have published their results as *Mém.* 9, *Archives de*

l'Institut de Paléontologie humaine. The skeleton was found in deposits on the slope of an escarpment, having been partially washed out by drainage from the upper parts of the slope of the rains of the previous season. It lay in a distorted position, partly on its right side with legs bent upward. Unfortunately the exposed parts had been broken off, leading to the loss of the greater part of the leg bones. It had not been buried, and did not appear to have been water borne. It is reasonable to conclude that it is contemporary with the fauna of deposits in the immediate neighbourhood identical with those in which the skeleton was found. Fresh-water shells and fauna, gazelles, antelopes, etc., now extinct in the area, point to these deposits having been laid down at a time when the Sahara was fertile and well watered, the site itself having been a fresh-water lake or a tributary of a river system long ago extinct. On the ground of the evidence as reported to them, the authors would attribute to the skeletal remains a high antiquity—certainly dating back to the pleistocene, and probably to a time corresponding to an early phase of the European *Âge du Renne*. Summarily stated, the characteristics of the skeleton are that it is male, tall, with limbs proportionately long, and dolichocephalic, with an index of 70·9. The face is mesoprosopic, approaching brachyprosopic, but at the same time very broad, thus being dysharmonic. The profile is mesognathous, but with strongly marked alveolar prognathism. The teeth are large. The nose is platyrhine and the orbits microseme. The upper incisors had been knocked out early in life. As a whole the skeleton presents marked negro or negroid characters. On a comparison with other types of fossil men, it differs markedly from the men of Afalou-bou-Rhummel, notwithstanding the cultural affinity of evulsion of the teeth, while it presents certain affinities with Grimaldi man, and although differing from the fossil men of South Africa, Boskop, Springbok, and others, in many respects, it possesses certain common facial characters which warrant its being classed with them as essentially of the African stock. The most marked difference is the high cranial vault. Among the living races it differs essentially from the Sudan negro, and its closest affinity is with the Bantu and Hottentot of South Africa, notwithstanding the fact that these are mixed races. This the authors would explain as due to the fact that these hybrids have preserved primitive features—certainly to a greater degree than the highly specialised Bushman. They would suggest, therefore, that the fossil man of Asselar represents an ancestral stock which split into two, one branch going north and developing ultimately into Cro-Magnon and to be correlated with the Capsian culture which appears in Europe as the Aurignacian, while another branch travelled

south to develop ultimately into the Bushman, Hottentot, and Bantu of that area.

Bourdeilles (*Dordogne*).—Attention must also be called, though unfortunately only the briefest reference is possible, to another important recent publication of the Institut de Paléontologie, a study of the rock-shelters and caves of Bourdeilles by M. Peyrony ("Les Gisements préhistoriques de Bourdeilles (Dordogne)," *Mém.* 10, *Archives de l'Institut de Paléontologie humaine*), in which the author describes the finds in the cave, several of them unique, and the art, basing on the latter a study of quaternary art. On the evidence of the culture of the caves as a whole, certain suggestions are offered as to racial movement in palæolithic times, and the relations of Solutrian and Aurignacian peoples and cultures.

Palestine.—While conditions in Egypt continue to be unfavourable to archæological exploration, and in Mesopotamia, except for some unforeseen good fortune, activity is likely to be devoted to the consolidation of what has already been won rather than the opening up of new fields, the investigation of the archæology of the Middle East may be expected to focus more and more on Palestine. Concentration on this area may look for ample reward in view of its geographical position and the effect of geographical conditions on the relations of Palestine and her neighbours in early times. The attention which has been given by members of the British School of Archæology in Jerusalem and the American School of Prehistoric Research to early man have produced within a comparatively short period material of the first importance, while the results which have already rewarded the first season's work in the resumed excavation of the city of Samaria have fully justified that undertaking. On two sites in particular, however, work has been done which is, or will be, of the greatest significance, sooner or later, in clearing up obscurities in the early history of Palestinian culture. These are the excavation of Jericho by Prof. John Garstang, and of Tel el-Ajjul, the ancient Gaza, by the British School of Archæology in Egypt under Sir Flinders Petrie.

Prof. Garstang completed his third season's work on the site of Jericho in the spring of this year. In the first two seasons he had failed to obtain any certain evidence of chronology, one of the main objectives of his research. By the opening of his third season he had, however, arrived at the conclusion that the conflagration, for which evidence had been found as the cause of the destruction of the city, had taken place during the late Bronze Age, probably somewhere about 1400 B.C. This conclusion was based, not only on the evidence of stratification, but also on the absence of any sign of Mycenæan contact. With a view to corroboration, attention was turned to the Bronze Age

cemetery some four hundred yards west of the city mound and twenty-five tombs were opened and cleared. A large number of objects, some eighteen hundred, mostly pottery, were obtained, covering the history of the city throughout the Bronze Age. Among them were ninety-four Egyptian scarabs, ranging from the Hyksos period to the reign of Amenhotep III; but nothing of the Tel-el-Amarna period or the age of Akhenaton came to light. It is therefore, he holds, legitimate to conclude that the city was destroyed somewhere between 1411 B.C. and 1375 B.C. An earlier rather than a later date in this period seems to be considered the more probable. There is evidence that people were living on the site in the Iron Age, but effective occupation and the rebuilding of the walls did not take place until about 900 B.C.

Sir Flinders Petrie's previous excavations on the site of Tel el-Ajjul in Southern Palestine have proved, in a sense, merely a prelude to the remarkable results which he achieved in the work of last season. He himself regards the site as one of exceptional importance, and holds that on it the early history of Palestine has been more fully explained than on any other in the country. Its culture extends from rock-cut tombs of the Copper Age, say 3400 B.C., in which copper daggers and pottery were found, to Tothmes III, from whose day the site was abandoned until reoccupied by the Arabs in the Middle Ages. No less than five palaces were erected on the hill, which was artificially extended to accommodate expansion. The first palace was erected by the people who introduced bronze from North Syria, the founders of the Eighth Egyptian Dynasty. It was probably the founders of the XIIth Egyptian Dynasty who built the second palace; and the third and fourth were the work of the Hyksos. An account of the results obtained appears in *Ancient Egypt*, 1932, Pts. 1 and 2.

Among the more noteworthy features revealed up to the present are the technical skill shown in the building of the large-scale Palace No. 1, with its stone basement and its bath chamber with plastered floor and its carefully arranged drainage slope to the outside of the palace. All later buildings were on a decreasing scale of size; and, indeed, this is one of the largest regular blocks of building known in Palestine. In Palace No. 2 the builders did remarkably regular work. The bricks of yellowish clay were so well made that later people took the walls to pieces in order to use the bricks.

Some remarkable evidence of cultural practice came to light, not yet susceptible of complete explanation. In late Hyksos times a curious place of offering was set up in front of the palace. In a brick tower about 15 feet square was found a chamber lined with rough stones and with a rough stone floor.

On this lay a quantity of personal jewellery—armlets, ear-rings, pins, etc., in gold and semi-precious stone. The chamber was filled with lumps of stone to about 3 feet deep. No such offering place is known elsewhere.

A remarkable deposit lying between the cemeteries and dating perhaps from about 2500 B.C. consisted of the remains of a great burning, in which two basalt tripod stands, an alabaster vase and slate dish, all broken, and a quantity of gold and silver work had been destroyed. All the gold plating had been torn into the smallest fragments. In the opinion of Sir Flinders, it is neither a burial nor hiding-place, nor is it loot. It is evidently the destruction of property which had to be annihilated for the common good. The parallel of Achan is cited. It would thus appear to be a Palestinian custom of expurgation, which came into usage among the Israelites.

Sir Flinders Petrie also contributes to *Ancient Egypt*, 1932, Pt. 2, a notice of the pictographic seal-inscriptions found in the course of the exploration by the Archæological Survey of India of the ancient civilization of the Indus valley. Sir Flinders essays an interpretation of the inscriptions on the presumptions, firstly, that being engraved on stone, like the Egyptian hieroglyphs, this pictorial system suffered little change in copying, and portrays in a more or less readily recognisable form the objects symbolised by each picture; and secondly, that the inscriptions on the seals, like those of Egypt, record titles of officials probably analogous to the official titles of Egypt, to which Sir Flinders has devoted considerable study. A large proportion of the inscriptions are tentatively interpreted on the basis of these presumptions.

Cornish Gold Hoard.—Before closing these notes mention must also be made of a study by Mr. Christopher Hawkes of the Towednack hoard of gold found on a farm near Penzance in December 1931 and May 1932, which appears in *Man* for August, with photographs of the objects. They were nine in number, four of them being personal ornaments, two torcs and two bracelets, two unfinished bracelets, and three twisted rods of gold, evidently the goldsmith's raw material. One of the torcs, three strands of twisted wire with the ends welded together and bent to form a clasp-hook, is unique; while the larger, a strand of twisted wire, is 45 inches long or slightly over, and a highly finished example of the goldsmith's art. Mr. Hawkes, using this torc as his basis of comparison, dates the hoard as belonging to the period of transition between Middle and Late Bronze Age, say, somewhere between 1000 and 750 B.C., and regards it as, possibly, marking the return of Cornish commercial activity which had died down during the Middle Bronze Age, but revived to culminate in the Iron Age.

ARTICLES

MODERN PHYSICS AND THE FIRST PRINCIPLES OF SCIENCE

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"I have no doubt whatever that our ultimate aim must be to describe the sensible in terms of the sensible."

J. H. Poynting.

"Nowadays we do not encourage the engineer to build the world for us out of his material, but we turn to the mathematician. . . ."

Sir Arthur Eddington.

No one who is acquainted with recent developments in theoretical physics can fail to realise that a very fundamental change is taking place as regards the methods and aims of the scientific interpretation of nature. Unfortunately it is far from easy to see exactly what this change is. This is due partly to the very ephemeral character of modern theoretical research and partly to the fact that different writers vary very much in the interpretation of its significance.

In a recent book by F. S. C. Northrop,[1] Assistant Professor of Philosophy at Yale University, an attempt has been made to view modern theories against a background provided by the early Greek philosophies. In this way Prof. Northrop succeeds in reviewing recent developments in a most fascinating and illuminating manner, and in the present article it is proposed to summarise his treatment as regards physical science, and to discuss certain advances which have occurred since his book was written. The book does not deal only with physics, but also with biology and psychology; in fact, it advocates a definite philosophy of nature. In spite of its originality and interest, however, we shall only mention it here in so far as it is required for an understanding of physics.

Northrop's thesis is that a sound knowledge of the first principles of science produces a genuine economy in thought, since, as the Greeks saw long ago, if the same problem occurs in

[1] *Science and First Principles*, Cambridge University Press, 1931.

many branches of science much trouble and time is saved by solving it first at the level of first principles. Further, considerations of first principles often enable a complicated theory to be shown to be unsound without wading through a mass of facts and figures : this is similar to the Method of Dimensions in physics in which, if the opposite sides of an equation are not of the same dimensions, it is certain that there must be an error in its derivation.

In order, therefore, to understand why the first principles of science are now being revised for the third time in twenty-seven centuries, we must go back to the ancient Greeks. Thales had noticed that nature is stuff, *i.e.*, it is composed of objects which have the quality of permanence, and Heraclitus noted that nature contains change. These are the great extensive characteristics of nature, and belief in them does not depend upon an accumulation of instances. The principle that nature consists of permanent objects and change is the principle that the real is physical : it is the basis of all physical theories. It was left to Parmenides to point out that the presence of these two extensive characteristics involves the existence of something else. His argument is brilliant and irrefutable. Change, he said, must be due to generation or motion. Generation is incompatible with the principle that the real is physical, since this involves eternal objects which do not change their properties. Therefore change must be due to motion. But motion requires that a body may move from where it is to where it is not. But if the body is stuff and the whole of the rest of nature is also stuff, there is no where-it-is-not, and motion is impossible. The problem is not overcome by regarding stuff as many rather than one, since manyness requires the possibility of distinguishing between one atom and another, and this is impossible if nothing but the stuff of the atoms exists. (Note that what is needed is a referent to distinguish one atom from another, more than an intervening medium.)

Heraclitus and Parmenides attempted to get over this difficulty by denying one of the facts. Heraclitus denied that there is any real permanence in nature, and asserted that reality consists of a flux in which matter is a mere appearance which comes and goes. Parmenides denied change, and said that it must be an illusion, and that nature is one huge spherical substance. But this denial of the obvious characteristics of nature was clearly unsatisfactory. Leucippus saw that another referent was needed to make motion possible, and when this referent was taken to be the spatial characteristic of nature which the Greeks called the " void," the foundation was laid of what later became the doctrine of absolute space, and with it

the kinetic atomic theory in a form which has remained unchanged down to the present time. This theory is the *physical theory* of nature. The extensive fact of nature, stuff, is accounted for by eternal atoms; the extensive fact of change is accounted for by the movement of these atoms, and the movement is possible because they are in absolute space. The atoms and space have fixed properties, so that the principle of being is satisfied, *i.e.* the real things composing the world do not change their properties, but are eternal. Absolute space has remained the background of the picture of nature drawn by science right up to the time of Einstein.

The consequences of the adoption of the physical theory of nature are of far-reaching importance. Firstly, it involves mechanical causation. Secondly, form can never be a cause of natural phenomena; it is due to motion of atoms which might produce disorder as easily; in fact, disorder is very much more probable, which is one form of the statement of the Second Law of Thermodynamics, which is thus involved directly in the physical theory.

We must now consider another theory adopted by the Greeks which we may call the *mathematical theory* of nature. This arose from the study of mathematics and astronomy, the dominant sciences of the Greeks; it began with Pythagoras and Eudoxus, and was finally developed by Plato. They noticed that the laws which they had used to bring several centuries of astronomical evidence into order and rational correlation were not concerned directly with physical objects at all. They referred instead to perfect geometrical forms and to ideal mathematical proportions. It seemed as if nature were a system of logical and mathematical forms rather than a collection of moving physical atoms. Thus it followed that the real is rational rather than physical. This is what Sir James Jeans means when he says reality is more like the mind of a mathematician than a collection of billiard balls. In fact, to see how the ideas of Pythagoras and Plato are arrived at from the study of modern, and therefore much greater, evidence one cannot do better than study *The Mysterious Universe* where these views are advanced with disarming *naïveté*.

Of several important consequences of such a view, now known as Platonism, we shall mention only a few: firstly, the primary causal importance given to relations; secondly, the distinction between the apparent world of bodies and motion and the real world of changeless mathematical form; and thirdly, since the real mathematical forms are not observed directly in nature, they can only be *suggested by* experiment, and do not follow by logical implication, which means that the deductive method is preferable to the inductive method. We

shall see these consequences much more clearly when we discuss the methods used by Sir Arthur Eddington.

The third great philosophy of the Greeks grew out of the study of biology, and is associated with the names of Hippocrates of Cos, Empedocles, and Aristotle. Hippocrates was the first to emphasise that a living organism is a mechanical system, and also that form or organisation was one of its fundamental characteristics. It was the mystery of organisation which forced Aristotle to an entirely new view of what was real in nature. It was impossible for him to attempt to account for the ordered growth and reproduction of living things by the motion of atoms which did not change their properties, owing to the elementary state of physical and chemical knowledge of his time. Organisation in living things seemed to involve form as a cause, as well as matter, and if this were admitted it meant, of course, that the physical and mathematical theories of nature had to be abandoned, since the former admitted only material causes and the latter only formal causes. And here we come to a very important point which is stressed by Northrop. Aristotle saw that to try to solve the problem of organisation by just retaining the physical atomic theory and adding on some organic formal relation as a cause is impossible, for the simple reason that there is no form apart from something which has form. If we are to force physical atoms to grow into a tree, we must act upon them physically—a disembodied form cannot do this. Thus Aristotle did not fall into the logical errors of the idea of emergent evolution which is still current to-day. Instead, he rejected the physical theory, and made matter and form attributes of some more fundamental and essentially different type of stuff. This stuff always exhibited both its material and formal aspects. But the formal aspect of nature is always changing, so that this more fundamental substance must also change its properties.

In this way Aristotle was led to the third of the great Greek philosophies, the *functional theory* which involves the principle of becoming, *i.e.*, the principle that what is real in nature changes its properties. This, of course, is in direct opposition to the principle of being, which is at the basis of the physical and mathematical theories of nature, and which asserts that the real is fixed and unchangeable. The doctrine of mechanical causation cannot appear in the functional theory, since reality is constantly changing its properties, and in order to forecast them we need to know final as well as present and past conditions: thus mechanical causation gives way to teleology.

These are the three great Greek philosophies of nature, and if matter and change are to be accounted for it must be in one

of these three ways. The Greeks, however, never decided upon which of them they would found the first principles of science. The implications of these three world-views are summarised by Northrop as follows :

" The physical theory implies (1) the principle of identity, (2) the priority of eternity over temporality, (3) the principle of mechanical causation, (4) the doctrine that all non-spatial relations are effects of atomic motion, and (5) the existence of a referrent in addition to the microscopic particles.

" The mathematical theory implies (1) the principle of identity, (2) the principle of mechanical causation, (3) the doctrine that only relations are causes, (4) the thesis that the method of hypothesis is the fundamental scientific method, and (5) the epistemological principle that the real world is suggested by, but not contained in, the world of sensation.

" The functional theory involves (1) the principle of teleology, (2) the primacy of the method of abstraction, (3) the epistemological principle that the real world is contained in the world of sensation, (4) the doctrine that matter and form are mere attributes of a process, or " event," or dynamic type of substance, and (5) the thesis that there is only one real individual in nature which is the " event," or process, or dynamic substance, termed nature as a whole."

In following the history of these theories up to the present time, we will pass over the early Platonism and later Aristotelianism of the Middle Ages to consider the foundation of the physical theory of nature which commenced with Galileo and Newton. This was the second time in the history of Western civilisation that the first principles of science were called in question. Galileo's formulation of the " science of local motion " was amplified and formally expressed by Newton in terms of mass, force, time, and space. Thus the physical atomic theory was born afresh ; nature consisted of the movement in absolute space of unchanging particles governed by forces which were properties of the particles themselves. The fact that force was considered as necessary only to *change* the velocity of a body, and not to maintain the motion as Aristotle had taught, involved the concept of inertia. Bodies not only remained at rest when no forces were acting but also continued to move if a force acting on them ceased. This inertial motion, Newton maintained, was " uniform " and " straight." Straight motion was defined by means of the then only geometry, that of Euclid : this, together with the defining of " uniform motion," involved Newton in the concept of absolute space and absolute time. Thus the referrent for motion which

Parmenides had shown to be required was taken by Newton to be absolute space. By absolute space Newton denoted space which "in virtue of its nature and without reference to any external object whatsoever, always remains immutable and immovable." This extraordinary statement means that this assumption is for ever unverifiable, since space itself is intangible, and if it has no reference to any object it can never be detected. Thus Newton violated his own principle of investigating only what is ascertainable by observation. The objectification of the idea of space in this unanalysed way would have been quite impossible to the Greek mind—they had no word for "space"—and could only occur, as Spengler has so amply shown,[1] to a mind in the late stage of what he calls the Faustian or Gothic Culture. These intuitive assumptions of absolute time and space lasted in science, as we know, right up till recent times, until the difficulties which they involved forced Einstein to deny them in his theory of relativity, and so to bring the first principles of science into question for the third time in history.

Before this happened, however, another absolute was added to the physical scheme, and this time it was a continuous substance, the ether. Newton's absolute gravitation, space, and time were systems of continuous relatedness, but the ether was a new stuff. It was natural to suppose that possibly this stuff and matter stuff were the same, and Lord Kelvin attempted to reduce continuous ether to discontinuous matter by means of his vortex atoms. But here again we are confronted with motion in a continuous substance, and this, as Parmenides had shown, is impossible. Let us repeat it: for the ether to move there must be somewhere not-ether for it to move to, say "space." Again, since Kelvin already believed in the atomic theory, the ether must be many and not one. Hence we have many ethers and space, *i.e.* atoms and absolute space, which is what the physical theory of nature already amounted to. No advantage therefore could be gained by the additional complication of vortices. If Kelvin had remembered Greek logic there would have been no vortex-atom theory.

Let us now consider what has happened to the first principles of science with the advent of the theory of relativity and the theory of quanta. With regard to the former, we know that at one stroke Einstein abolished, with the special theory, absolute space, absolute time, and absolute ether, and substituted absolute space-time. Then with the general theory he abolished absolute space-time and absolute gravitation and left only matter and the tensor equation for gravitation, which specifies how matter determines the metrical structure of the

[1] Oswald Spengler, *The Decline of the West*, Allen & Unwin.

four-dimensional space-time surrounding it (which is therefore relative). Suddenly, therefore, the physical theory of nature has been shorn of all absolutes except matter. A more thorough-going physical theory has never been propounded: even the metrics of space and time and space-time which were regarded as independent of matter, are now "defined at every point by the matter at that point, and the state of that matter" (Einstein [1]).

Now, according to Northrop, although so clearly a physical theory of nature, nevertheless it is unsatisfactory in a very important particular, for we are left without any referent for atomicity and motion. For, apart from the difficulty of motion, atomicity is impossible if there exists only moving particles and their relations to one another. It is the argument of Parmenides again. We shall not follow here Northrop's solution of this difficulty by the postulate of another physical body, the "Macroscopic Atom," which surrounds the whole universe, since the arguments are chiefly of a philosophical nature, and Northrop's own presentation must be studied in order to appreciate it fully. We shall content ourselves with remarking that it is not so ridiculous as appears at first sight, and there are many suggestive analogies between Northrop's physical views and those of recent mathematical investigators. We must now continue to trace the fluctuations between the different Greek views of nature by considering extensions which have been added to the general theory of relativity, the theories of the finite universe and the unitary field theories.

The difficulty with regard to the universe as a whole has changed recently from one which involved keeping its parts together to one which involves making them run away from one another. At the time of Einstein's original suggestion of a finite universe (1917) the problem was the former one, and may be stated as follows: taking the universe as a whole astronomical evidence justifies the use of statistical mechanics, that is to say, the matter in it is spread more or less uniformly and the equipartition of energy also holds approximately,[2] and we may therefore treat it as though it were a gas. Now in such a system there was nothing, according to Newtonian mechanics, to prevent both bodies and radiation escaping into outer space. In fact, statistically the Newtonian universe could not exist.[3] It was to overcome this difficulty that Einstein suggested that the universe might be spatially finite. But if we examine Einstein's original hypothesis of a cylindrical universe,

[1] *The Principle of Relativity*, Einstein and Others, p. 183 (Methuen).

[2] J. H. Jeans, *Nature*, **122**, 691 (1928).

[3] A. Einstein, *Cosmological Considerations on the General Theory of Relativity*, loc. cit., p. 177.

i.e. one with constant curvature in spatial dimensions, we notice that he has to add another tensor to his formula for the law of gravitation involving a constant λ (the "cosmological constant"). Now, although Einstein up to this point had stood solidly for the physical theory of nature, repeating again and again that the gravitational potentials $g_{\mu\nu}$, which determine the structure of space-time, depend only on matter and the state of that matter, nevertheless, when he came to this additional term, he did not define it explicitly in physical terms, and admitted quite frankly that nothing in our knowledge of gravitation justifies it.[1] Thus, it can hardly be said that Einstein's cylindrical universe is much better physically, with regard to this particular problem, than the Newtonian model.

This temporary lapse on Einsten's part in failing to define gravitation in terms of matter was magnified unblushingly by de Sitter, who proposed a spherical universe (curved in time as well as space) which did not contain either matter or radiation! Thus de Sitter openly proposed a view of nature which was not founded on matter, and which was, in fact, a purely geometrical one. This was one of the first steps in the gradual abandonment of the physical theory for the mathematical theory of nature, carried further afterwards by Weyl and Eddington.

By 1929 the evidence for the recession of the spiral nebulæ (the most remote objects in the universe) had become much more imprèssive: it appeared as if, with a few exceptions, they were running away with velocities proportional to their distance from our galaxy. Consequently attention was withdrawn from static models of the universe and concentrated on expanding ones. Lemaître was the first to examine the consequences of the hypothesis of an expanding universe,[2] and since then many others have been proposed.[3] It then became clear that there is no need in such a scheme for the cosmical constant λ which was introduced *ad hoc* to keep the universe stable.[4] Einstein therefore proposes to drop it, since it never had a definite physical basis.[5] The point to notice here is that the hypothesis of an expanding universe has a definite physical meaning, since (if we interpret the red shift of the nebular spectral lines as due entirely to motion) there actually are enormous masses moving systematically away from our galaxy. In maintaining an expanding universe and dropping λ, Einstein is still holding to a physical view of nature. On the other

[1] A. Einstein, loc. cit.

[2] *Monthly Notices R.A.S.*, **91**, 483 (1931).

[3] Cf. R. C. Tolman, "Models of the Physical Universe," *Science*, **75**, 368 (1932).

[4] Actually Eddington showed that even with the λ term Einstein's universe was unstable for small changes.

[5] Einstein and de Sitter, *Proc. Nat. Acad.*, March 1932.

hand, the statement that a set of mathematical relations (space-time) is expanding is meaningless on the physical theory.

But we must remember that all these cosmological theories are highly speculative, and if the change over from the physical view of nature to the mathematical depended only on attempts to bring order into the universe on a large scale, we should not feel compelled to take it very seriously. It happens, however, that in recent attempts to explain the behaviour of atoms, the mathematical theory of nature has emerged again and in a very forcible manner. But before we pass to a consideration of the atomic theory we ought to notice briefly the nature of the unitary-field theories which have been proposed in order to account for electric and magnetic forces in addition to those of gravitation.

It was clear that it would be a great simplification if a structure for space-time could be found which would determine a body's motion under electromagnetic as well as gravitational forces. Attempts were made in this direction, the three most important unitary-field theories being those of Weyl, Eddington, and Einstein. Now in the general theory of relativity the metrical curvature of space-time was variable (depending on the disposition of matter), and this meant that two rods could only be said to be parallel in any absolute sense, when they were infinitely close together. But in defining the curvature it was assumed that the length of the rod remained the same for finite displacements. This was described by saying that there was metrical but not gauge curvature.

This suggested to Weyl that perhaps the other variables could be obtained by introducing gauge curvature as well, *i.e.* by assuming that equality of length only held for infinitesimal displacements. This assumption gave him four extra variables, and when they were identified with the four electromagnetic potentials, the extra equations which he obtained turned out to be Maxwell's equations. This, as Eddington says, was "unquestionably the greatest advance in the relativity theory after Einstein's work."[1] But, unfortunately, it gave predictions which were not in accord with fact, and so a distinction had to be drawn between the geometry of the theory and the geometry of nature.[2] This, however, did not prevent Eddington from going a step farther, and generalising Weyl's gauge-curvature, by allowing for the fact that a rod may vary in length when rotated about a given one of its points as well as when transported over a finite distance. In this way he got a more complicated tensor requiring many more variables to be

[1] A. S. Eddington, *Mathematical Theory of Relativity*, p. 198 (Camb. Univ. Press).

[2] A. S. Eddington, loc. cit., pp. 196 *et seq.*

specified before the metrical curvature of a given space-time frame can be determined. Actual values for all these variables do not occur in the world of experience. In this way Eddington gets a lot of spare " material," or " lumber " as he calls it, and we shall consider later the way in which this lumber drives him to a philosophy which will enable him to keep those portions which he wants, and discard others which have no counterpart in the real world.

The important point to notice here is that Weyl's theory is not, as Weyl originally thought, on the same footing as the general theory of relativity: it is not a physical theory, it is partly pure mathematics and partly physics. And further, Eddington's theory is admittedly a mathematical theory, depending on his notion of infinitesimal parallel displacement which " has some significance in regard to the ultimate structure of the world—it does not matter much what significance."[1] Einstein, however, repudiated the methods of Weyl and Eddington,[2] and in 1928 he published his unitary-field theory, in which he obtained the extra potentials for electromagnetism by discovering that he had restricted himself unnecessarily in formerly assuming that measuring rods could only be said to be parallel when infinitely close to one another, and that it was possible to have distant parallelism within the four-dimensional metric of the general theory without its being Euclidean. In this way he obtained a unitary field theory which he claims to be a true physical theory and not a mere mathematical curiosity,[3] although he admits that a physical basis was lacking, and he was guided only by mathematics and logic.[4]

But, as we have remarked before, the research which has played the greatest part in favouring a change from the physical to the mathematical view of nature, is that which attempts to account for the behaviour of matter on the atomic scale. Here, as everyone now knows, a new philosophy of science and its method has been adopted, and so successful has this been that a number of prominent mathematical physicists now regard it as the only possible approach to the fundamental properties of nature.

The new method originated with the realisation that Bohr's atomic model on classical mechanical lines, in spite of the continual addition of arbitrary quantum restrictions, was totally inadequate to account for the behaviour of elements of high atomic number, and also for dispersion. This led Heisenberg and Born to introduce a new way of attacking the problem:

[1] A. S. Eddington, loc. cit., p. 213.
[2] A. Einstein, *Math. Annal*, 97, 99 (1927).
[3] *Nature*, 126, 897 (1930).
[4] *Nature*, 127, 826 (1931).

they made no attempt to conceive of orbits within the atom, or of any mechanism whatever, but restricted themselves to the observable quantities only, viz. the frequencies of the spectral lines. Science must deal only with measured quantities and mathematical relations. The great success of this method with the help of matrix algebra (*i.e.* a calculus of pure form) led to the belief that it was the fundamental way of investigating nature. Physical models and ideas were only snares and delusions. In other words, there was a return to the mathematical theory of nature. Dirac introduced still more general mathematical conceptions, from which the theory of matrices follows as a special case.

With the wave-mechanics of de Broglie and Schrödinger, there appeared, at first sight, to be hope of a return to a physical theory of nature by conceiving of the electron as composed of ψ-waves in some sort of medium. Unfortunately, in cases in which more than one electron was considered, it was found necessary to use more than three dimensions, and as there is no warrant for this in the physical world, it became clear that "the square of the modulus of ψ" could not represent the electric density. Consequently, it has no meaning in a physical theory, and a mathematical meaning had to be found for it—it represents the "probability" of finding an electron at the point considered. But probability has a meaning only in the theory of knowledge; it has none in the theory of nature. An attempt to give probability an absolute meaning in nature by denying causality has, however, attracted a great deal of attention recently. This has arisen through a particular interpretation of the principle of indeterminism.

The principle of indeterminism states that it is impossible to determine accurately both the position and the momentum of an electron at a given instant.[1] Now, although the principle was brought to the front by the adoption of wave-mechanics (it would be fairer to call it wave-mathematics), nevertheless it has a definite physical meaning, and that is what gives it importance, an importance, however, which is estimated differently by different writers.[2] We have already seen that the philosophy of the new physics is to deny the existence of anything that cannot be given in an experimental determination. This is sometimes likened to the procedure in the theory of

[1] This is here stated in terms of electrons and motion, *i.e.* in accord with the physical view, but this is not necessary, as it can be stated in terms of probability.

[2] Cf. F. A. Lindemann, *The Physical Significance of the Quantum Theory*, Oxford, 1931. H. Dingle, *Science and Human Experience*, Williams & Norgate, 1931. M. Planck, *The Universe in the Light of Modern Physics*, Allen & Unwin, 1931. A. Einstein, "Letter to Sir Herbert Samuel," Presidential Address to British Institute of Philosophy, Kegan Paul, 1932.

relativity. There is, however, a very fundamental difference. It was *theoretically possible* to determine velocity absolutely with respect to the ether, and when nature appeared to prevent this again and again, *i.e.* it was *impossible practically*, it was undoubtedly excellent scientific procedure to suppose that we were looking for something which did not exist, and therefore to change the theory. But in the case of the principle of indeterminism things are quite different. It was *theoretically impossible* (as well as practically) to determine accurately the position and momentum of an electron at the same instant. There is nothing mystical about this—it follows from the fact that radiation has momentum. Consequently there is no particular reason to change the theory so completely as to say that when we talk of the position and momentum of an electron, we are talking of something which does not exist. We cannot say that because this practical determination is impossible, therefore the theory must be wrong, when the theory itself denies the possibility of accurate practical determination. It is only those who hold that only things which can be observed in a physical experiment have any meaning, who can put this interpretation on the principle of indeterminism, and infer that there is a basic uncertainty in nature, and hence proceed to deny causality. It was therefore the greatest absurdity for Heisenberg, who held this view, to describe the principle in terms of electrons and motion, since electrons are never given directly in a physical experiment. In fact, Heisenberg has now abandoned this philosophy, and admits that the observational verification of every scientific concept is an impossible ideal.[1]

We see, then, that the whole tendency of modern theoretical physics is in the direction of a mathematical theory of nature. All ideas of physical representation have to be renounced, and all that we can do is to fit numerical observations into systems of mathematical relations, which are merely suggested by the observations and do not follow from logical necessity.

It will be noticed that so far we have not had occasion to refer to any form of the functional theory of nature. A modern form of this theory does, however, exist, and is advocated very powerfully by Prof. A. N. Whitehead. As far as physics is concerned this theory does lead to a theory of relativity, but it is not the same as Einstein's, and we shall not attempt to consider it here.

In order to see the mathematical investigation of nature in operation, and to get some idea of its drawbacks, and of the philosophy to which it leads, we cannot do better than attempt to follow the activities of one who is, perhaps, its greatest

[1] W. Heisenberg, *The Physical Principles of Quantum Theory*, Univ. of Chicago Press.

exponent, Sir Arthur Eddington. Not only are his expositions of greater lucidity and precision than those of other writers, but they also face the philosophical implications more frankly. As we have already seen, Eddington's exposition of the theory of relativity is one which involves the mathematical theory; space-time and its curvature are undoubtedly primary and matter only secondary, and further, we saw that his initial mathematical assumptions are of a very general nature. Consequently, of the prominent relativists, it was he who was in the best position to enter the new symbolic physics and to link up the equations of macroscopic physics—the cosmological theories—with the equations of the microscopic sphere—electrons and protons. This he has recently succeeded in doing in a most brilliant and startling manner.

Since Eddington believes in the primacy of space-time which *is* a construction of pure form—a set of mathematical relations—it follows that when he uses the deductive method, and starts "world-building," it is with mathematical symbols that he starts—*relations* and *relata*: "The relata are the meeting points of the relations."[1] Then making his assumption about the comparability of infinitesimal displacements, which we have already noticed, he finds that the most general structure of a four-dimensional space-time requires 256 numbers for its definition. However, most of these give the same result, and finally only 40 are left, but still there are far too many, for in a unitary field theory only 16 coefficients of curvature are required, 10 $g_{\mu\nu}$'s to represent the curvature due to gravitation, and 6 to represent that due to electric and magnetic forces. The only thing that Eddington can do, therefore, is to *discard* the other 26 coefficients. These he calls "lumber." But those who hold the mathematical theory of nature, that is to say, those who believe that what is real in nature is perfect forms and mathematical relations (*e.g.*, space-time), are bound to face the problem of why all the relations and forms that can be known by reason are not found in the actual world of experience. This can only be done by falling back on the conscious mind, and saying that the mind chooses to "actualise" some of them and not others. "Not once in the dim past, but continuously by the conscious mind is the miracle of the creation wrought."[2]

Thus the phenomenal world is made to depend upon the mind and nature is said to be only known to reason. This inevitably leads to mysticism and a decline in interest in crude experiment carried out by means of the senses. As Eddington

[1] A. S. Eddington, *The Nature of the Physical World*, p. 230 (Camb. Univ. Press, 1928).
[2] A. S. Eddington, loc. cit., p. 241.

himself says: " In one sense deductive theory is the enemy of experimental physics."[1] The history of science from Plato to the Middle Ages is a logical sequence. At any rate, it must surely be a fine point in epistemology to decide which is the more objectionable—to account for nature by a physical theory with arbitrary quantum restrictions invented *ad hoc*, or to use the mathematical theory with copious arbitrary discardings (or " lumber ") equally *ad hoc*. However that may be, there is no doubt that at the moment the mathematical approach to nature is bearing fruit with extreme abundance, though it has the drawback that its fruits are very perishable and only the mind can tell which are edible.

Eddington enters the atomic field by arguments of the following kind.[2] Electric charge only manifests itself when we have two or more electrons. The interaction of two electrons is a consequence of their charge. Consequently, if we have any relation which defines their interaction, it ought also to define the charge e as well. By the use of the Exclusion Principle, which defines the interaction of two electrons, and extending the principle of relativity to include the case of change of identity as well as change of axes, he gets $\frac{hc}{2\pi e^2}$ to be 137, where h is Planck's constant and c is the velocity of light. The experimental value is 137·1.

Again,[3] Eddington's particular interpretation of the law of gravitation and, in particular, of λ the cosmical constant, enables him to say that, in the wave equation of the hydrogen atom, which determines the linear " spread " of the charge, this linear spread must be related to the radius of curvature of the spherical world at the given place and in the given direction. He searches, therefore, for a term in the equation which is likely to contain R, the world radius. With a few very plausible assumptions he succeeds in getting not only R but the square root of the total number of electrons in the universe as well. What is more convincing, however, is that he can calculate the rate of recession of the spiral nebulæ, and this result turns out to be within 10 per cent. of the observed value—a truly remarkable achievement. It is a great misfortune that it is only if one holds the mathematical theory of nature that one can accord significance to these brilliant researches. On the physical theory it is very difficult to see what meaning they can have, unless, perhaps, we invoke something in the nature of Northrop's " macroscopic atom." At any rate there are several

[1] A. S. Eddington, *Mathematical Theory of Relativity*, p. 238.
[2] Cf. A. S. Eddington, *Proc. Soc. Roy.*, A, **122**, 358 (1929).
[3] Presidential Address to the Physical Society, *Proc. Phys. Soc.*, **44**, 1 (1932).

suggestive analogies: for instance, Northrop maintains on logical grounds that there is no meaning in atomicity and motion except with reference to the encircling "atom"; Eddington insists on logical grounds that there is no meaning for measurement unless it is with respect to the world radius R.[1] Again, Northrop says that the quantum restrictions to the electronic orbits are due to the interaction of the fields of the microscopic particles and the field of the macroscopic atom; Eddington, speaking of the hydrogen atom, says: "The wave equation must say just as much about the radius of the world as it says about the spread of the constituents of the atom."[2] Further, Northrop points out that there will be a constant in nature connected with the radius of the macroscopic atom and the total number of particles within it: Eddington likewise calculates the ratio of the square root of the number of electrons to the radius of the universe, and gets

$$\frac{\sqrt{N}}{R} = \frac{mc^2}{e^2}$$

where *m* is the mass of the electron.

Such analogies may not be as suggestive as they appear, but those who still hold the physical view of nature are bound to attempt, sooner or later, to account for these results in physical terms. Eddington, for instance, talks of the "expansive force" which makes the universe expand, even in the face of gravitational attraction which tends to make it contract. Is it a new force? There is no answer physically. It is connected with the $\lambda g_{\mu\nu}$ term, which, as we saw, never had any physical justification. But it is essential to Eddington's position, and consequently when Einstein proposes to drop it altogether, he can only regard it as "an incredibly retrograde proposal."[3]

So finally, if we are asked to sketch the present position of physics, we should have to do it somewhat as follows: At the entrance to a cave, in the face of a cliff of solid rock, stands Einstein. He complains somewhat sadly that nowadays he is looked upon as just a little crazy[4] for sticking to the rugged cave when he might enjoy the comforts of a more modern home in the plain below. He seems undecided whether to leave for good or not.

Inside the cave, Sir J. J. Thomson, surrounded by tubes of force, is busily engaged in a little simple cooking. Farther in still, a rough, and sometimes violent, game of billiards is in

[1] A. S. Eddington, Presidential Address to the Physical Society, loc. cit.
[2] *Ibid.*
[3] Loc. cit.
[4] Lecture at Nottingham, *Nature*, **125**, 897 (1930).

progress: it is Lord Rutherford and his satellites; they are playing a new game on a very old table. Every now and then they succeed in splitting one of the balls completely and several others show signs of cracking. Someone thinks he has found a new kind of ball which is not red or white like the others, but the light is rather poor, and it is difficult to judge colours well enough to be quite sure.

Outside, down in the plain, in the sunshine and the dust, a vast new building enterprise is at work. It is the Mathematical and Symbolical Development Company. Its directors despise the simplicity and austerities of cave life; for they believe that they can make more comfortable dwellings by the adoption of a new method. This involves seizing almost anything they can lay their hands on—the most unlikely things, in fact—and then starting an orgy of construction. The result is that a great many of the things they build don't look like houses at all: some have no walls; some have no roofs; some are inside out; some fall down before they are finished. But they do not mind so long as, every now and then, they achieve something which can reasonably be said to look like a house.

Let us descend into the plain and examine the new estate more closely. We must not be surprised if, at first, we feel the architecture to be somewhat bizarre, for we have always had a predilection for symmetry, but these new builders declare that nature is really antisymmetrical.

The first estate we come to belongs to one of the biggest and most efficient contractors—Sir Arthur Eddington. Let us talk to him over the wall. He is busy *contracting* now, he says, and adding *relata* to *relata* and cementing them by means of *relations*. He cannot think of anything simpler than that. In the background a group of workmen are engaged in raising and lowering *suffices*. He admits that there is an occasional hitch in the construction, and that in some of the houses there is great difficulty in getting upstairs, as he hasn't found a reliable way of making staircases yet, but he hopes to remedy this in time. Apart from minor defects of this sort, it must be admitted that his houses have a charm of their own and many are of very great elegance. Unfortunately, it is very hard to view them really well, as they are surrounded by great mounds of rubbish and odds and ends—"lumber," he calls it. If we ask him why he lets them accumulate like this, he replies: "The things which we might have built, but did not, are there just as much as those we did build."[1] It seems rather a drawback to the method of construction: however, he tells us that this is the 136th house he has built, and he can go on for some time before he exhausts all the possibilities.

[1] *The Nature of the Physical World*, p. 241.

In the shade of one of the larger buildings a young man named Dirac is juggling with some symbols, but his ideas are even more peculiar than those of the others; it is very hard to say what he is doing, and there is some doubt whether he knows himself. Anyway, the buildings he has erected bear a close resemblance to others on a neighbouring estate built on a less obscure plan.

As we move across to examine these others, Sir Arthur Eddington shouts after us: he is sorry; it was not house No. 136 that he was building, it was No. 137. In counting, he had overlooked one which had been hidden by piles of lumber!

Looking at the houses on the next estate, that of Schrödinger and de Broglie, we see what appear to be rows of army huts made of corrugated iron, but closer inspection shows that although there is something corresponding to the corrugations there is nothing corresponding to the iron. On asking a workman what the material is, we are told that it is just waves of probability.

On the next plot the buildings of yet another firm of architects are rising up. The architects are Heisenberg, Born, and Jordan. They seem to favour something like ferro-concrete: at any rate, there are large rectangular grids lying about, which they call *matrices*. Unfortunately, in order to build really reliable houses, these matrices have to be infinite, which would seem something of an obstacle in a finite estate. We cannot see the workmen at work, as they are protected by large hoardings. This is because Heisenberg has realised that if you inspect a process too closely *you alter it*, and he is not running any risks.

As we turn back towards the cave which still seems to be our safest home, a loud explosion rends the air. No one takes much notice: this happens every few months, they say. It is probably a row of houses on the new estate collapsing; or perhaps Lord Rutherford has split another billiard ball; or could it—could it be that Sir J. J. Thomson has overstrained a tube of force?

THE BEARING OF GENETICS ON THEORIES OF EVOLUTION

Address delivered before the Royal Society of Dublin, January 31st, 1932.

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We are all familiar with the story of the Tower of Babel, one of the strangest and most dramatic of the Old Testament. The peoples of the earth, having, at that time, a single universal language, and constituting apparently a single nation, arrive, under the leadership of the heroic Nimrod, on the fertile plains of Shinar. There they determine to erect a central city, and a colossal tower, worthy of a world-metropolis, and reaching even as far as heaven. Whether the motive of this grandiose project was merely, as the text says, to make a name for themselves, as in the case of the transatlantic sky-scrapers, or whether it was the ambition of the leaders to establish a colony in the Utopian region beyond the clouds, is not made altogether clear, for the Deity, we are told, put a stop to the entire project by confounding the language of the builders, so that they could no longer understand each other.

A common metaphor represents the labours of men of science as the construction of a gigantic edifice, upon the wings and annexes of which workers in different branches of natural knowledge are engaged. The various methods and techniques in which we have been trained correspond to the crafts of the different classes of artisans, the stone-cutters, masons, plasterers, sculptors, and painters, whose co-operation is needed to produce a finished and habitable building. The contemplation of this similitude, of the savants of all nations proving, by their example, that man is capable of something better, and more fruitful, than the pursuit of international rivalries, or mutually destructive contests, whether by economic or by military methods, has certainly in it something both elevating and encouraging. Yet the old story of the Tower of Babel, itself a noble, though doubtless a presumptuous and misguided, enterprise, bears a sufficient resemblance to the edifice of science for it to contain, perhaps, some hints to guide us in our own endeavours.

We are not told exactly in what manner the confusion of tongues originated; whether by a sudden and miraculous transmutation in the word-centre of each individual, he began forthwith and, all unconscious of the change, to express his ideas in a babbling jargon, meaningless to his fellows; or whether, as the work progressed, groups of workers so concentrated their attention upon special parts of the building, and on the particular technical problems of their crafts, that they gradually came to use words unintelligible outside their own little circle; or, still worse, to use the old words with meanings quite unknown to the workers on the floor above, until their old common language had been lost irrevocably.

Enterprising men, especially kings, have from time to time endeavoured to ascertain experimentally what was the primitive tongue spoken in the infancy of mankind, before diversity of language had arisen. James IV of Scotland, for example, had two children reared by a dumb foster-mother, in solitude, on the island of Inchkeith. When old enough, it is said that they gave tongue in excellent Hebrew. Against this encouraging result we must, however, set the definitely negative conclusion of a much more thoroughly replicated experiment by the Mogul Emperor, Akbar Khan. In this case thirty "parallels" were employed, who, on growing up, since they spoke no particular language, confirmed the sceptical Emperor in his adhesion to no particular religion.

If we were to ask, on the other hand, what universal language could enable men of science to understand each other sufficiently well for effective co-operation, I submit that there can be only one answer. If we could select a group of men of science, completely purge their minds of all knowledge of language, and allow them time to develop the means of conveying to one another their scientific ideas, I have no doubt whatever that the only successful medium they could devise would be that ancient system of logic and deductive reasoning first perfected by the Greeks, and which we know as Mathematics. Deductive and inductive reasoning, to change the metaphor, are the means by which alone we can ascertain whether or not a new slab of observational fact will fit into its place in our edifice; and the mathematical expression of such reasoning is the only effective cement which we possess, by which such new facts can be held fast as parts of a coherent structure.

I do not at all anticipate that this view will be readily conceded. It is quite contrary to the prevalent opinion, for which mathematicians themselves are largely responsible, that mathematics is the most specialised and isolated of scientific studies. It is contrary, too, to that scheme of classification of the sciences, which, I believe, originated with the philosopher

Compte, in which we ascend a kind of hierarchy from mathematics, the simplest and most fundamental, through physics and chemistry, to the biological sciences ; and thence, with increasing dignity and importance, to psychology, and to the Queen of the Sciences, sociology. Although votaries of the natural sciences generally would doubtless repudiate this particular monarch, this arrangement appears to have been really influential in the organisation of our universities, and of our scientific societies. It is familiarly incorporated in that aphorism which defines chemistry as " the messier part of physics—and the cleaner parts of biology " ; it was doubtless responsible for the fact that when the publications of the Royal Society of London were divided into two concurrent series, A and B, mathematics should have been without question included with the non-biological, and excluded from the biological group of sciences.

Such a division is logically indefensible. What is more important is that it is becoming inconvenient. Mathematics has been described as the subject in which we never know what we are talking about, nor whether what we say is true, and the description, though something of an over-statement, has the merit of emphasising the important fact that it is the method of reasoning, and not the subject-matter, that is distinctive of mathematical thought. A mathematician, if he is of *any* use, is of use as an expert in the process of reasoning, by which we pass from a theory to its logical consequences, or from an observation to the inferences which must be drawn from it. Speaking thirty years ago, it would have been proper to speak of mathematics as providing the technique only of deductive reasoning. Such a limitation would no longer be appropriate at the present time ; for, owing primarily to the work of " Student," mathematically exact inferences *can* now be drawn from the sample to the population—from the particular to the general—in an important and increasing class of cases. I refer to the Tests of Significance. The importance of this advance, for human thought in general, is, I believe, roughly equivalent to that of the first mathematically exact use of deductive reasoning, by the Greek geometers of the generation of Euclid. It is not my purpose now to enter into the logical revolution effected by " Student's " work ; but it has this immediate bearing on our subject, that, whereas the points in which the physicist requires mathematical aid lie chiefly in the deduction from a theory of its logical consequences, the biologist most frequently needs assistance in the inductive process by which general theoretical conclusions are drawn from bodies of observational data.

How greatly this has become a practical need, in all fields

in which biological work is being put upon a quantitative basis, will not easily be realised without personal contact with the scientific workers, agronomists, entomologists, botanists, geneticists, marine zoologists, and many others, from Europe, Asia, Africa, and America, who, in the first five or ten years of their research experience, discover that their really urgent practical problems are essentially statistical ; and who, if they are fortunate enough to have the opportunity, apply to attach themselves as voluntary workers to a statistical research laboratory, such as the department for which I am responsible at Rothamsted. Diverse as the qualifications of these workers are, they all have this in common—that while they are of a generally high intellectual capacity, they have received, in their university training, no preparation whatever for the statistical problems which are bound to confront them, as soon as they come into real touch with the questions they are set to investigate.

That is one criticism of the unnatural separation of mathematics from biology, with which I am brought personally into daily contact. What I want to discuss more particularly this evening is an historical example, by which we can judge of the effects of this separation, not on the work of any one individual, but on the course of development of a whole science. I propose to illustrate the general theme of the function of mathematical contacts with the sciences by reference to a little Babel of misunderstandings which has occupied, for a generation or two, the principal court of that part of the edifice of Science in which the biologists are at work.

Faraday and Darwin were alike in possessing transcendent powers in scientific reasoning and experimentation. By some chance of character or upbringing they were both devoid of any command of mathematical symbolism. The one devoted his life to physical and chemical, the other to geological and biological, researches. There is the basis, one might say, of a well-controlled experiment. For Faraday's discoveries were early taken up by mathematicians, especially by Maxwell, and built into a coherent electro-magnetic theory, so firmly and compactly that almost alone of the older physics it has survived the revolution caused by quantum theory and wave-mechanics. Meanwhile, accident contributed to delay the application of mathematical ideas to Darwin's theory of Natural Selection. While the *Origin of Species* was being written, the Austrian monk and mathematician, Gregor Mendel, must have been already conducting his experiments ; and six years later was able to demonstrate, in the garden pea, those statistical laws of inheritance which have since been verified throughout the animal and vegetable kingdoms. His work was fully published

in a not very obscure journal, but was ignored and forgotten for thirty-five years. Presumably, it was not the kind of work which the German-speaking biologists of the time were prepared to appreciate.

If the neglect of Mendel's work for a whole generation forms a striking illustration of my theme, the immediate reactions of its rediscovery in 1900 illustrate my point even more remarkably. For two of the most prominent exponents of the importance of the new knowledge, Prof. Bateson in England, and Prof. de Vries in Holland, had already, in the nineties of the last century, made themselves notable advocates of the theory of discontinuous evolution of specific forms—the theory of evolution *per saltum*, as opposed to the gradual process of selective modification proposed by Darwin. They, therefore, seized upon the discontinuous hereditary factors demonstrated by Mendel's work, as though these had been specific differences, instead of differences, generally, between close varieties ; whereas, as we now know, forms which are ranked by systematists as specifically distinct, differ, as a rule, not in one, but in a large assemblage of Mendelian factors.

The discovery of an essential fact unknown to Darwin ought, naturally and properly, to have formed the basis of a criticism and revaluation of Darwin's theories. The particular use to which it *was* put, however, showed that neither the logical consequences of the Mendelian laws, nor the logical place in Darwin's reasoning of the erroneous "blending" theory of inheritance, were appreciated by the most prominent writers in the early history of Mendelism.

A rather careful examination of Darwin's writings, and especially of the reasoning in his two unpublished essays, in which he first developed his views, is needed to discover exactly to what extent, and in what ways, the theory of blending inheritance, which he accepted, influenced his deductions. The principle of Natural Selection itself is wholly unaffected. If a population exhibiting heritable variability experiences differential rates of mortality, or of reproduction, its average character will on any view be gradually changed. The urgent question which assailed Darwin's early thought was whether natural populations could be assumed to contain an abundant supply of heritable variability, and this, on a blending theory of inheritance, is really an urgent question. For by the continual blending of the characters of different parents all variability must be rapidly annulled. Speaking mathematically, the quantity of variability, or "variance," as we call it, will, approximately, be halved in each generation, and this carries with it two important consequences:

(i) That causes of new variability, or "mutations," as we should now say, must be exceedingly abundant (they must account, for example, for all heritable differences between whole brothers, for their entire ancestry is identical). And,

(ii) That practically all the heritable variance available for selection to work on must be of extremely recent origin, ascribable to mutations occurring within about the last ten generations.

Darwin rested his theory on the demonstrated fact that domesticated animals and plants certainly possess sufficient heritable variability to be modified perceptibly by the human breeder; but his theory was harassed by the possibility that such heritable variability might be absent or rare in wild species, being due to quite recent mutations, induced, in domesticated species, by the conditions of domestication themselves. Hence his elaborate attempt to ascertain by inductive reasoning what are the circumstances of domestication which induce abundant mutation, and, judging these to be changed conditions and increased food supply, his inference that these circumstances must also act, though much less intensely, upon species in a state of nature. Darwin's difficulty in this respect is entirely removed when we replace the blending theory by the particulate theory of Mendel. On the particulate theory there is no possibility of the variance dying away rapidly. The existing variance is due not principally to recent mutations, but to mutations which have occurred during thousands or tens of thousands of past generations. The greater variability of domesticated species is evidence, not of a higher mutation rate under domestication, but only of man's proclivity for selecting and propagating novelties, and for the survival, under the shelter of a domesticated environment, of types which could not survive in the wild state.

The second inference from the blending theory, by which speculations were embarrassed, lay in what we should now call the enormous mutation-rates which it requires should be postulated. Darwin had no objection to these high mutation-rates, for no experimental data as to the actual rates of mutation then existed; but he recognised that in a system in which almost every individual born was a mutant and even a multiple mutant, the environmental circumstances by which mutations might be expected to be controlled, or at least influenced, might themselves possibly be powerful agents of evolutionary change. He was therefore extremely ready to believe in "the direct effects of environment," although, by the study of the adaptive mechanisms of animals and plants, he was continually being brought back to the conclusion that such direct effects in fact achieve extremely little.

Now all possible theories of evolution fall, in this matter, into two classes. In the one class is Natural Selection, the efficacy of which is proportional merely to the actual amount of heritable variance maintained in the population, and is totally unaffected by whether that heritable variance is supplied by a mighty flood of mutations, which are always rapidly wasting away, or by a feeble trickle of mutations, the variability due to which is jealously conserved. In the other class fall all theories of evolution in which the direction of evolution is itself supposed to be governed by the direction in which mutations are occurring. Thus the Lamarckian theory postulates not merely that a mechanism exists by which use-modifications are able to induce mutations in the germ-cells, but requires the further postulate, that the mutations so induced are capable actually of controlling the evolutionary changes in progress in the organism. The case for and against has been invariably discussed in reference only to the first postulate. The second postulate has not, until recently, seriously been challenged ; but it is the more important of the two, for it is equally necessary to all such other theories as "Orthogenesis" and "Nomogenesis," by which it has been hoped to account for evolutionary modification. Now it is this second postulate, that evolutionary modification can be governed by the kind of mutations which are occurring, that is challenged by the particulate theory of inheritance. When we reject the blending theory and accept Mendelism we thereby cut down the supply of mutations by at least ten thousand fold. And calculation shows that they are no longer able to avail against even the faintest adverse selection.

That is the quantitative aspect ; and it is fully in accordance with our deductions so far, that even the largest mutation-rates, determined experimentally, seldom exceed 1 in a million in each generation. But it is the qualitative aspect which will appeal most to biologists, because it allows the greatest scope for observational verification. If, as so many theories have assumed, evolutionary change is governed by the occurrence of mutations, whatever may be the mechanism (Lamarckism, Orthogenesis, etc.), by which it is supposed that such mutations are induced, it follows that the mutations must, generally speaking, cause changes of the same kind as those which have occurred in the course of evolution ; changes, that is, towards greater complexity of organisation, and more perfect adaptation to the conditions of life, and to the ecological relations with other organisms. The breeze of mutations by which evolution is supposed to be wafted forward must not only be sufficiently powerful, but must be very prevalently in a favourable direction. Again, the experimental evidence is

decisively against such a view. Some two or three hundred mutations have been studied in the fruit fly *Drosophila*, and of these not one can be said to be advantageous, while the great majority are patent defects and deformities. In addition to these, however, the most numerous class of all are actually lethal, the mutant form being totally incapable of development, and perishing, either in the egg, or at an early larval stage. That the vast majority of mutations should be deleterious is a perfectly natural consequence from the view that the organism is maintained in a highly adapted condition by natural selection, for a highly adapted condition can mean nothing else than one which is more easily injured than improved by a change in its organisation. But the observation is incompatible with the view that evolutionary change is governed by mutations, unless we are willing to believe that those organisms so far studied have almost run their evolutionary course, and are rapidly plunging towards degeneration and extinction.

From considering the two views which have been held upon the nature of inheritance, we have been led to divide theories of evolutionary modification into two classes, contrasted, and sharply contrasted, in one single characteristic. On the one hand the great majority of evolutionary speculations have rested on the unformulated assumption that it would be sufficient, to explain any particular evolutionary change, if we could explain why mutations in that organism had occurred in a particular direction. The fallacy is the common one of assuming that the truth of a proposition implies the truth of its converse. The extinct reptile *Diplodocus*, for example, evolved a neck some 20 or 30 feet long. It can, I think, reasonably be inferred from this, that in the course of its evolution a succession of mutations must have occurred, the effect of which was, amongst other things, to lengthen the neck. These mutations are *necessary*, but they are not *sufficient* to explain the particular evolutionary modification which has taken place. What cannot be inferred is that, given the occurrence of such mutations, the lengthening of the neck must follow. Had this converse proposition ever been explicitly stated, and challenged, it would have been evident that no solid grounds could have been put forward in its support, and that numerous facts well established in other organisms rendered it totally untenable. If we knew, for example, that mutations lengthening the neck were occurring now in the crocodile, we should have no reason to think that the average length of neck was increasing in that species.

But it is as well here to emphasise the limitations of our knowledge. Mutations occur so scantily that it is only possible

to study them in organisms in which enormous numbers can be bred and examined. The conclusions I have mentioned from the genetical work on the fruit flies are based on the examination of between 20 and 30 million specimens, and it is obvious that, though our direct knowledge of mutations will doubtless become more detailed, and more exact, we cannot hope that it will ever become, biologically speaking, extensive. Biologists, too, have every reason to be cautious of extending conclusions from one group of organisms to another; and, if we are to accept the view that evolution, in the hundreds of thousands of plants and animals which have evolved, has made its way in the face of a blizzard of predominantly unfavourable mutations, containing only a small minority of those that are favourable; if, I say, this is the *prevalent* condition of evolutionary change, we may well ask whether it has not left unmistakable traces throughout the length and breadth of the animal and vegetable kingdoms. I believe this reasonable challenge can be met; at least, if we accept certain recent interpretations of genetical phenomena, which appear at present to have substantial observational support, but which will probably be more exactly scrutinised in the near future.

There is, widely observable both in plants and animals, a remarkable tendency to exogamy, which Darwin summarised in the phrase that Nature abhors perpetual self-fertilisation. Among animals, especially those which move freely about, the separation of the sexes is the general rule, and, even where they are hermaphrodite, we generally find either that pairing is obligatory, or that cross-fertilisation is favoured by special devices. In the vegetable kingdom, the importance of cross-fertilisation seems to be the dominating factor in the evolution of the whole group of flowering plants, and to have reacted in a most important way on the evolution of the higher orders of insects. Not content, however, with obtaining facultative cross-fertilisation in this way, numerous additional adaptations are found, which, in certain groups, render it almost or quite compulsory, such are the separation of the male and female inflorescences on the same plant, as in *maize*, the separation of the sexes in different plants in the *hop*, the development of self-sterility in the *tobacco* plants, and that curious form of self-sterility known as hetero-stylism, which in the *primroses* and other genera divides the species into two or three castes, or genders, all hermaphrodite, crosses between which are required for normal fertility. In animals, the separation of the sexes seems to have been sufficient in most species; yet we cannot fail to associate with the same series of phenomena that dread, which seems to be widely felt in mankind, of the marriage of near kin; and, some years ago, Dr. Metz of Baltimore found

in the genus of fungus gnats, *Sciara*, an intricate genetical mechanism, which distinguishes the females into two classes, male-producers and female-producers, respectively. More recently, Dr. Barnes has shown that the production of unisexual families is widespread in the large family Cecidomyidæ (gall midges), and, as these species are exceedingly short-lived, and mate immediately upon emergence, we may see in this complex mechanism an adaptation to prevent the constant mating of brothers and sisters, which, pupating in close proximity, would otherwise very frequently interbreed.

Darwin was led by phenomena of this kind, and by the strong suspicion of the danger of inbreeding entertained by live-stock breeders, to demonstrate experimentally, with a number of species of plants, that the offspring obtained by self-fertilisation were, on the average, less vigorous in their growth than the offspring obtained by cross-fertilising the same parent plants. Naturally much speculation was provoked as to the reasons for which cross-fertilisation stimulated, or self-fertilisation impaired, vigour; and it was for long widely believed that a mere difference in the genetic elements combined exerted some generally beneficial and stimulating influence. More recent work has carried the matter a good deal farther, and has given a much clearer conception both of the facts and of their causes. The facts cannot be better exemplified than by the extensive researches which have been carried out by American geneticists on maize.

When a maize plant is self-fertilised, and its progeny continued in a number of self-fertilised lines for several generations, the deterioration in yield and in the vigour of vegetative growth is striking; and perhaps even more surprising is the complete recovery to the full ancestral vigour, obtained, in a single generation, by crossing two of these stunted lines. That alone shows that the racial stock has not been injured. Moreover, a study of the different lines shows that while all are usually inferior in some respect or other to the average commercial maize plant, the defects of different lines are strikingly distinct and individual. Moreover, the experiment of self-fertilisation can scarcely be carried out without revealing, in one or more of the lines, a distinct segregation of sharply marked defects, such as failure to develop the green pigment, chlorophyll, of the leaves. These defects are readily demonstrated to be simple Mendelian recessives. The conclusion is forced upon the investigator's mind that innumerable other recessives of the same kind, but indistinguishable by reason of the similarity of their effects, are responsible for the general lack of vigour by which all the inbred lines, though in very different degree, are characterised. This explanation imme-

diately makes sense of the fact that, in other plants, such as wheat, self-fertilisation may be continued generation after generation without ill-effects; or that close inbreeding of brother and sister may be continued, apparently indefinitely, as has been done in certain lines of rats; or that even in species intolerant of inbreeding, such as guinea-pigs, lines may, with sufficient trouble, be found in which inbreeding may be carried on generation after generation without loss of health or vigour. It is the habitual cross-pollination of the maize plant, when grown commercially for seed, that has permitted the accumulation of the great swarm of defects which are revealed by self-fertilisation. In species commonly self-fertilised such recessives would be quickly eliminated, and the habitual procedure in scientific maize improvement now lies in the selection of those self-fertilised lines which are most free from serious defects, and which, on crossing, do, in the first or second generation, outyield every commercial variety of maize obtainable.

The injury observed on close inbreeding is thus exposed in an entirely new light. It is not perpetual self-fertilisation, but the first few generations, and especially the first generation, that is dangerous. The inbred lines show no perceptible further deterioration after eight or ten generations. Moreover, it is not the racial potentialities that are injured, but only the individual expression of them. It is not the species, but the individual, which suffers. The various devices which exist in nature to ensure exogamy are not for the benefit of the species, for which, so to speak, Natural Selection cares nothing, but to ensure the well-being of the immediate progeny; to guard them against the recessive defects, which may lie latent in their parents.

Just as we can understand the meaning of the devices which ensure cross-fertilisation, if we already know that self-fertilisation is liable to have immediately injurious effects, so, in turn, we can explain the injurious effects of self-fertilisation when we know that Mendelian recessives are invariably, or preponderantly, harmful. But why should this be so? Why should there not be as many harmful dominants with correspondingly beneficial recessive allelomorphs? Or, simpler still, why should either form be dominant or recessive, instead of producing a cross intermediate between its parents? It is to this question that I believe some quite recent developments are able to afford the answer. But in speaking of them I ought to say that I am expressing my own personal opinions, rather than a body of well-established and authenticated conclusions. Some years ago, in speculating on the Mendelian phenomenon of dominance I was led to make a classification

of the non-lethal mutations which had appeared in the most fully studied of the fruit flies, *Drosophila melanogaster*. Out of 221 different mutations available for classification I found that 208 were described as recessive; that is to say, that in these cases the cross-bred or heterozygous fly appeared to be completely normal, and the mutation was entirely concealed. In not one case did the cross-bred fly resemble the pure-bred mutant. But in the 13 remaining cases it was intermediate, showing a defect of the same kind as the mutant, but of less intensity. The distribution of these mutations in respect of dominance or recessiveness was therefore extremely one-sided. That was a fact which influenced me greatly. A second fact which seemed to throw a direct light on its explanation is observable in what are known as series of multiple allelomorphs. In many cases the same gene has experienced, in different individuals of the same species, mutations of different kinds, and we have, as in the Albino series in rodents, an original gene, which determines full pigmentation, and a series of mutant genes which determine different degrees of dilution of the coat colour, extending, in some cases, as far as complete albinism. Using the five genes of this series available in the guinea-pig, Sewall Wright combined them in the fifteen possible ways in which pairs may be chosen from five different sorts of things; five being homozygous, or containing a pair of genes of the same sort, and ten heterozygous, compounded of unlike genes; and he bred a sufficient number of animals of each combination to study the average depth of pigmentation, and its variability within each type, both in the black and in the red portions of the coat. He found that the five homozygous combinations were all perfectly distinct with very little variability compared with the differences between the average intensities. Of the ten heterozygous or cross-bred classes, four, which were compounded of the non-mutant or wild-type gene, and one or other of its mutant derivatives, were all completely indistinguishable from each other, and from the pure wild-type coloration. The remaining six heterozygotes, however, were in every case clearly intermediate between the two homozygous types from which they had been derived. The whole body of observations may be summarised in the two rules: that the wild-type gene is completely dominant to all other genes of the series, whilst between these other genes dominance is entirely absent. Now these two rules are found to hold very generally in the many series of multiple allelomorphs which have been studied in other organisms; and since such an arrangement would be overturned whenever, in the course of evolutionary change, any gene happened to be replaced in the wild population by one of its mutants, unless

at the same time the relationship of dominance became reversed, it appeared to me to follow necessarily that dominance, which is after all only the developmental reaction of the organism to a particular gene-combination, was itself a by-product of the evolutionary process.

The mutations which we can observe in the comparatively few individuals which can be kept under experimental observation must represent, on the whole, those which are occurring with the highest mutation-rates, and which must occur regularly in enormously greater numbers in the wild populations. Moreover, many of them must have been occurring in the past for perhaps millions of generations. We know this because we find different related species giving rise to the same mutations. Such a history is, of course, only possible for disadvantageous mutations, always kept rare, in spite of their continual occurrence, by counter-selection ; and in such a situation it may be shown that selection will continually favour the modification of the heterozygote towards the normal condition, and only when the heterozygote has become completely normal, and the mutation has become completely recessive, will any appreciable modification of the homozygote commence to take place. If this second stage also were completed there would be nothing left for the geneticist to observe, and this stage can only be demonstrated in such a favourable case as is afforded by the little tropical fish, *Lebistes reticulatus*, where certain mutants affecting the coloration appear to be beneficial in the male, but unfavourable in the female fish, and where the visible effects have been almost completely suppressed in the female.

I should very unduly prolong this lecture if I were to attempt to give any full account of the experimental evidence on which this theory of the evolutionary modification of dominance can be supported. I have recently put forward the case in some detail in a paper in *Biological Reviews*, and I can do no better now than to mention one very decisive instance for which, when I wrote, the evidence was still incomplete.

The New World cottons form a group of species particularly favourable for genetical research, for the reason that while distinct in many good taxonomic characters, they are mutually fertile, and give fully fertile hybrids. In the Sea Island cotton a mutant known as Crinkled Dwarf has been frequently observed to appear, although it apparently does not occur in other species of New World cotton. In the course of his experiments in Trinidad, Dr. Harland happened to cross a Crinkled Dwarf Sea Island plant with two other American species.

In the first generation the crinkled character appeared not

to be completely recessive, for the hybrids showed slight signs of crinkling; and, on self-fertilising these, instead of obtaining three-quarter normal and one-quarter crinkled plants, little more than a quarter were normal, while the remainder showed a totally unclassifiable series of all grades of crinkling. The importance of this case, for the theory of the origin of dominance, was at once recognised by Dr. Hutchinson, Dr. Harland's assistant; and the more crucial experiment was set on foot of introducing the Crinkled Dwarf mutant, by successive back-crossings, into a pure race of Upland cotton. The later generations show that, in the Upland species, Crinkled Dwarf is neither a dominant nor a recessive. The heterozygote is about as much dwarfed as is the homozygote in Sea Island; while in Upland the homozygote is so extremely dwarfed as to be scarcely viable. Moreover, the stages by which this condition was reached during the experiment indicate, Dr. Harland tells me, by the diminishing variability of the crinkled character, that Sea Island cotton differs from the other American species in a group of modifying factors, which together act to make the Crinkled Dwarf mutant completely recessive in that species. It may well be long before we have stronger or more direct evidence that the recessiveness of mutations is itself a consequence of a prolonged evolutionary process, by which each species reacts to the unfavourable mutations with which it is persistently peppered.

If we are asked, then, what evident traces have been left on the organisation of plants and animals in general, by their having made their evolutionary progress in the teeth of a shower of predominantly unfavourable mutations, we can point in succession to three very widespread phenomena. First, the absence of true dominants, and the abundance of recessives, among mutant genes as compared with the genes prevalent in wild populations; the recessives have become so, *because* they are unfavourable; next, to the injury experienced on self-fertilisation, or inbreeding, in populations in which harmful recessives have been allowed to accumulate; and thirdly, to the separation of the sexes, and all other similar devices to favour exogamy, which are evident adaptations for avoiding this injury. Wherever any of these three phenomena can be demonstrated, there we have evidence that the evolutionary process has not been favoured, but predominantly opposed by the mutations which have occurred. Every theory of evolution which assumes, as do all the theories alternative to Natural Selection, that evolutionary change can be explained by some hypothetical agency capable of controlling the nature of the mutations which occur, is invoking a cause which demonstrably would not work even if it were known to exist.

In short, the net results of substituting the idea of particulate inheritance, in accordance with Mendel's discovery for the previous notion of blending inheritance, has been to remove the chief logical difficulty to the theory of Natural Selection, by which Darwin was harassed in the development of the theory, and at one blow to dispose of every alternative proposal which has been made to give a rational account of the evolutionary process. When we cast our minds back over the history of biological theories, both in the last quarter of the nineteenth century and in the first quarter of this, it is, I submit, a question worth considering whether a sympathetic contact with mathematical ideas would not have induced such continuity in the grasp of the logical purport of the arguments used at different periods as would have obviated the chaotic misunderstandings which are so marked a feature of this history. Incidentally I believe that the popular reputation of biology will be raised, and some of the *point* of mathematics will be more widely recognised, the more thorough and extensive such intellectual contact can be made. In the present movement towards a fuller development of the mathematical ideas underlying biological theories, a movement which is active not only in these Islands, but also in Germany and the United States, it is principally the biologists, such as Haldane, Bernstein, and Sewall Wright, who have taken the initiative. It is therefore more particularly for mathematicians to consider whether the academic organisation of their studies is competent to foster, or destined to retard, this further extension of their application.

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RECENT DEVELOPMENTS IN SPECTRUM ANALYSIS

By A. HARVEY, Ph D., B Sc

In 1834 one of the earliest workers in the field of spectrum analysis showed that flames coloured by lithia and strontia were distinguishable quite easily by means of the spectroscope, although they could not be differentiated by the eye. Talbot [1] wrote: "Optical analysis can distinguish the minutest portions of these two substances from each other with as much certainty, if not more, than any other known method."

A serious obstacle in the path of the development of the subject lay, however, in the persistency with which the yellow D-lines appeared in all spectra. This obstacle was removed by Swan [2] in 1856, when he found that an extremely small quantity of sodium (of the order of $2 \cdot 5 \times 10^{-8}$ grams) was sufficient to produce the D-lines, and that the almost invariable appearance of these lines in the spectrum merely illustrated the remarkable diffusion of sodium and furnished a beautiful example of the extraordinary delicacy of the spectroscopic test.

This obstacle removed, Bunsen and Kirchhoff [3] proceeded—in addition to discovering the two new elements cæsium and rubidium—to place spectrum analysis on a firm basis. Their work established the fact that each element had its own distinctive spectrum, and they were quick to realise that the new method of analysis they had provided was not subject to the limitations in space from which previous methods of chemical analysis had suffered. They realised that they had opened up the way to the study of the chemical composition of the Universe as a whole, and Kirchhoff [4] immediately commenced a study of the elements present in the sun,[1] whilst a few years later Huggins and Miller [5] commenced similar work on the stars.

The realisation that the emission spectrum was an unmistakable characteristic of each metallic element was the foundation-stone of spectrum analysis, and, so long as there were new elements to discover on the earth, or elements to be

[1] It should be noted that in 1852 Brewster had concluded that the dark Frauenhofer lines were produced by the vapours surrounding the sun.

identified in the stars, there were many workers in the field. Since the beginning of the twentieth century, however, the emphasis has been on the analysis of spectra, rather than on spectrum analysis, and it has only been within the past few years that there has been any considerable further progress made in the latter subject. These recent developments concern both the qualitative and the quantitative sides of the subject, and have had as their prime object the rendering of the subject of increased value to industry.

Qualitative spectrum analysis has now been in use for many years. Even so, an important step forward has recently been made by Ryde and Jenkins working in the Research Laboratories of the General Electric Company, Wembley, in the introduction of R.U. (Raies Ultimes) Powder. This consists of carefully adjusted small quantities of about fifty of the elements incorporated in a base composed of calcium, magnesium, and zinc oxides. The adjustment of the amounts is such that only a half-dozen or so of the more important sensitive lines of each element appear when the spectrum of the powder is excited by burning it in a carbon arc. An extremely rapid method of spectrographic analysis is thus furnished ; the process consists merely of the photographing, adjacent to the spectrum of the unknown substance, of a comparison spectrum of the R.U. powder. Then, by reference to photographic charts, the identification of the constituents of the substance under investigation can be performed without even determining the wavelengths of the spectrum lines. The majority of the elements detectable in this manner are metals or metalloids, but it is possible to modify the method so as to detect combined fluorine [6], and probably this modification could be extended. A trace of CaF_2 is present in the R.U. powder and, as a result, the green calcium fluoride bands appear in the spectrum in fair strength. If fluorine is suspected in the substance under examination the addition to it of a trace of a calcium salt furnishes, by the presence or otherwise of the calcium fluoride bands, a sensitive test for fluorine.

Ryde has also been responsible for the development of the exploded-wire method employed in the analysis of fine wires and filaments. The original problem was the detection of the spectroscopically insensitive element thorium in wires which might be only 0·0016 cm. in diameter and of which only a few centimetres length was available (the mass being of the order of 0·2 mgm.). It was found that the thorium lines showed up more readily the greater the excitation, and eventually the method was adopted of exploding a bank of condensers (of up to 0·05 m.F. capacity) through the wire. Under such conditions very often the explosion of a single wire 1·5 cm. in length was

sufficient to register the spectrum with a large quartz spectrograph, and it was found that as little as 0·02 per cent. thorium and 0·005 per cent. of many other impurities could be detected in tungsten. Later work has shown that the method can be made quantitative, and that fine wires of many types can be analysed by means of it.

Turning to the quantitative aspect of the subject, apart from isolated estimates of the minimal amounts of various elements detectable spectroscopically, only two methods received much attention prior to the last few years. Hartley [7], whose work was extended considerably by Pollok and Leonard [8], showed that (in general) the lines of a metallic element disappeared progressively as the content of that element present in the source was reduced. Hence, after results had been obtained showing the lines present at different concentrations, it was a fairly simple matter to lay down upper and lower limits for the composition of the source. The other method consisted of the visual comparison of a spectrogram of the substance with a series of spectrograms of specimens of known composition. Gramont used this method extensively, and a considerable amount of work has been performed by means of it.

If either of these methods is to be employed to the best advantage, then some method of standardising the conditions must be employed, since it is well known that variations in the discharge are liable to affect the relative intensities of spectral lines. The fact that lines due to the neutral atom and to the ion of the atom respectively are also known as "arc" and "spark" lines is sufficient illustration of this. It follows, then, that a fairly rigorous control of discharge conditions must be maintained if consistent results are to be obtained from quantitative spectrum analysis. A simple method has been devised whereby the effects of small deviations in routine and of fluctuations in the source itself may be eliminated; the importance of this was first clearly insisted upon by W. Gerlach, after whom it is generally known as Gerlach's "Internal Standard Method." [1]

In this method the intensity of a line of the minor constituent under estimation is compared with that of a line due to the main substance, or to that of a line due to some foreign substance purposely introduced (in known amount) to act as a standard. The assumption made is that slight fluctuations in conditions will affect the intensities of both members of the "line-pair" in the same way, and that their relative intensities will thus

[1] The method is discussed in considerable detail in the book, *Foundations and Methods of Chemical Analysis by the Emission Spectrum*, W. Gerlach and E. Schweitzer.

remain unaffected. Provided that the lines are suitably chosen (*e.g.* an arc line must be compared with another arc line and not with a spark line) the method works extremely well in practice, and takes care of the minor variations which occur. The use of the method is well illustrated in most of the work which will be quoted here.

Returning to the two main lines of attack upon the problem of rendering spectrum analysis quantitative, the first of these has recently been employed by Brownsdon and van Someren [9] in a very comprehensive survey of the application of spectroscopy to the analysis of lead and brass alloys. These investigators have for some years been using spectroscopic methods in routine examinations and, as a result of this experience, they have published a number of valuable tables embodying the necessary data for the estimation of, for example, aluminium, iron, lead, nickel, manganese, and tin in brass, and similar minor constituents in lead and lead alloys. They conclude from their experience that a spectrograph should be an essential part of the equipment of a metallurgical laboratory.

In a very different field from that just described, Ramage and his collaborators [10] [11] are employing the second of the two quantitative methods mentioned earlier in order to examine the distribution of elements in the animal kingdom, the examination being made semi-quantitative in the manner indicated. The use of the spectrograph in this work was dictated because of its yielding an analysis with a rapidity with which chemical methods could not compete. In the first of the two papers so far published a description is given of the analysis of annelids and of the organs of molluscs. It is found that iron and copper are present in every tissue examined, whilst other elements are peculiar to certain organs. The second article deals with human tissues, and amongst the mass of information obtained may be mentioned the fact that copper, a universal and probably an essential constituent of living tissue, occurs in considerably greater concentration in fœtal tissues than in adult tissues, reaching its maximum in the fœtal liver. Rubidium, it is observed, is almost as widely distributed as copper, and occurs in greatest concentration in the heart and striated muscle.

The limitations of the methods just discussed are obvious, since in any interpolation method the accuracy obtainable is limited by the magnitude of the steps employed, and in the methods described the steps were generally large and the accuracy correspondingly small. It is obvious that any improvement in the accuracy of the analysis is dependent upon an increased accuracy being obtainable in the measurement of the

intensities of the spectral lines, since the fundamental assumption in this type of analysis is that the line-intensities are dependent upon the content of the element in the source. There have been two main lines of improved technique in this direction. In one of these the densities of the line-images on the photographic plate are compared by means of a microphotometer (employing either a photoelectric cell or a thermopile), and this comparison is made by observing the varying intensity of a beam of light as it passes through the various line-images. Although this adds considerably to the time and labour of making determinations, it is clearly a great improvement upon the original method where merely visual comparisons were attempted of the plate blackening.

Although it is rather difficult to estimate the accuracy obtainable in this manner, certainly the claims for a 1 per cent. accuracy attainable in routine measurements may be dismissed. Where every precaution is adopted in an investigation of the intensities of spectral lines the error of any single comparison of two intensities may be as much as 4 per cent. In such investigations, however, the relative intensities of the lines are only obtained after a careful calibration and standardisation of the plate has been made. These precautions are rendered absolutely essential because of the very complex nature of the phenomena associated with the photographic plate, one of the most important of which, from the point of view now being considered, is that the characteristics of a plate are dependent upon the wavelength employed. Unless precautions such as the above are adopted, and if merely a direct comparison is made of the microphotometer deflections given by an ordinary spectrogram, it seems probable that only under favourable circumstances will an accuracy of 5 per cent. of the content be obtainable.

In the other method which has been adopted in an attempt to improve the accuracy of quantitative spectrum analysis a device is employed whereby when the spectrogram is actually being obtained the exposure is made to vary along the slit of the spectrograph, so that at one end of the slit a very much longer exposure is given than at the other (the ratio of the two extreme exposures may be 500 : 1). This variation in exposure along the length of the slit is produced by the rotation in front of it of a disc whose periphery is cut to a logarithmic curve (*see* diagram), the instrument being known as a logarithmic sector. The net result of using the instrument is to produce on the plate lines whose lengths are a logarithmic function of their intensities [12, 13]. In this method the determining factor with regard to the accuracy obtainable is the accuracy with which it is possible to measure the lengths of the lines. The uncertainty here is

such that—in a quantitative analysis—an accuracy of some 10 per cent. is obtainable at present, but work in progress leads to the belief that it may be possible to improve upon this. In actual practice a "line-pair" is employed, one member of the pair being due to a major constituent, the other being a line of the metal under estimation. Thus the minor constituent is estimated in terms of the major constituent, the logarithm of the ratio of the intensities of the two lines being directly proportional to the difference in their lengths. Since the ratio of the intensities varies with the concentration of the metals, it follows that a correlation is obtainable between the composition

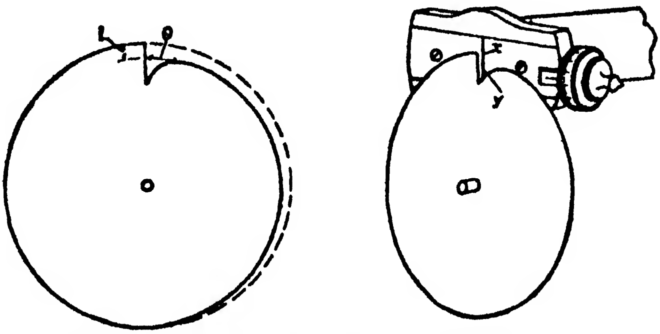

Diagram of logarithmic sector disc ($-\log \theta = 0{\cdot}3 + 0{\cdot}2\, l$), and *right*: cut showing sector disc in position in front of the slit *x y*.

(Reprinted by permission of the Royal Society.)

of the substance and the difference in length of the members of the "line-pair."

It is important to notice, in passing, that spectroscopic methods in general yield an accuracy which is independent of the total content under estimation. Thus, if the accuracy of the method is stated as 10 per cent., it means that a substance which is present to the extent of 10 per cent. in the substance under analysis is determined as (10 ± 1) per cent., whilst another substance present to the extent of 0·10 per cent. is determinable as $(0{\cdot}10 \pm 0{\cdot}01)$ per cent. Hence, although spectroscopic methods can lay no claim to great accuracy where high percentages are concerned, when low percentages (say, under 1 per cent.) are involved the accuracy obtainable is very satisfactory and compares favourably with that obtained by chemical analysis, whilst compared with the latter method of analysis a great saving of time is almost always possible. Again, chemical separations are often incomplete. Gravimetric analysis is dependent upon differences in the solubility of salts, and this factor, together with the common occurrence of occlusion of other salts during precipitation, may cause quite considerable

errors unless extreme precautions are taken. Further errors in routine examinations may be caused by the appearance of impurities not normally present, causing side reactions and altering the course of the separation.

A number of investigations have been made employing the logarithmic sector, one of the most recent being that by Twyman and Hitchen [14]. This work was confined wholly to solutions, and a new type of sparking tube was evolved in order to obtain a discharge truly representative of the liquids. Solutions containing chromium, nickel, and similar metals were employed, and it was found possible to estimate the metallic content with an accuracy of 10 per cent. of the metal present, the range of concentration varying from 0·01 per cent. to 5 per cent. The sector has also been employed by Twyman and Harvey (unpublished work) for the estimation of chromium, manganese, and nickel in steels, the discharge in this case being an arc between two specimens of the sample under test; here also the estimation gave results accurate to some 10 per cent. It is of interest to note that in both of these investigations the majority of the elements studied exhibited line-intensities which were directly proportional to the content of that element in the substance undergoing analysis. This is in agreement with the results obtained by Barratt and Carrod (unpublished work) in a study of the variation of the intensities of the spectral lines of silver and gold in alloys composed wholly of these two elements. In this case the variation of intensity along the slit of the spectrograph was produced by means of a platinised quartz wedge. The range covered by these investigators was a most extensive one, the composition of the alloys ranging almost from one pure metal to the other. Whilst over this extensive range the course of the variation of the line-intensity of an element with the percentage content of that element proved to be very complex, it was observed that for percentages of the order of those employed by Twyman and his collaborators the intensities of the lines varied linearly with the percentage content of the element.

We have already referred to the "Internal Standard" method for standardising conditions, and have stated that this is the means most generally employed. There is another technique, however, which deserves separate description in view of the possibilities attaching to it. This latter is due to Barratt, and is known as the "Twin Spark" method; it is only applicable conveniently to spark spectra, whereas the Internal Standard method does not suffer from this restriction. In the "Twin Spark" method two sparks are run in series, the electrodes of one spark consisting of (say) rods of a material whose composition is accurately known, whilst similar rods of the

substance under analysis form the electrodes of the other spark. The sparks are run in series, hence variations in the electrical conditions of the discharge should be the same for both sparks. The content of the metal under estimation being different for the two sets of electrodes, a known reduction in intensity is imposed upon the radiation from the spark with the higher content, so that the intensity of a selected line appears the same in both spectra. For the visible region the estimation may be made either visually or photographically. Visually, a nicol prism is placed in the beam emitted by each spark, the axes of the prisms being at right angles to one another. Then, before the two beams enter the spectroscope, a third nicol prism acting as an analyser is interposed, and this is rotated until the line in question has the same intensity in both spectra. From graphs previously prepared it is possible, knowing the angle through which the analyser has been rotated, to deduce the content of the unknown specimen. Photographically, the intensity of the stronger beam is reduced by means of a rotating sector. A number of photographs are taken with various sector openings, and thus, by interpolation, the sector opening necessary to produce equality in intensity is deduced. A high degree of accuracy is obtainable by means of the instrument and technique described, but so far there has been no extensive employment of the method.

Whilst examination of the literature of, say, the past ten years will disclose a number of other methods by means of which spectrum analysis may be rendered quantitative, it will be found that none of these differ essentially from those described here, and, in general, they are either modifications or combinations of these latter. The applications, however, have been very numerous and diverse, and one or two types of these have already been indicated. One of these applications, though, has received extensive development in the hands of D. M. Smith (Spectroscopic Investigator to the British Non-Ferrous Metals Research Association), and a reference to this work must be included in our review.

Smith's work has consisted of the application of a number of the methods we have outlined to the testing of works products for conformity with various specifications, and it has shown that these methods are eminently suited to this purpose, that they can be employed for the routine testing of materials, and that they are of very definite use in the elimination from a works output of those portions of it which contain more than a certain percentage of impurity. For example, he has shown [15] that spectroscopically it is a simple matter to differentiate one from another samples of zinc containing 0·75, 0·25, 0·1, 0·05, 0·01, and 0·001 per cent. of cadmium, whilst a similar

differentiation is possible with regard to the iron and lead contents of the samples. The percentages quoted lie within the range of the limits of the British Standards Institute specifications, and it will be obvious, then, that—purely by simple spectroscopic methods—it is possible to grade foundry zinc in conformity with the present-day specifications. In view of the tedious and difficult nature of the chemical assay this work possesses a peculiar value. Later work by the same investigator [16] has shown that it is possible to estimate the content of antimony, cadmium, and tin in lead and lead alloys with an accuracy quite high enough for the ordinary control of production, and, in this case, the spectroscopic assay can be performed in thirty minutes as compared with the five hours required for the chemical assay.

Finally, within the past few weeks, Judd Lewis [17] has published details of the technique and materials necessary for what he has termed the "Ratio Quantitative System" of spectrographic analysis. As an illustration of the method we may consider the analysis of a vegetable ash. An average percentage composition for such a substance would be Ca 10, Mg 10, Na 5, K 35, PO_4 35, Si 5. A powder is available of this composition, and it is obtainable "medicated" in known amounts with the metals which are to be estimated. Thus such a powder could contain *relative to the calcium content* (or to the content of any of the major constituents) 0·1 per cent. of each of the following: Li, Na, Sr, Ba, Al, Fe, B, etc., or 0·01 per cent., or again, 0·001 per cent. By comparison of the spectrograms of the "Ratio Powder" and of the ash under investigation it is thus possible to determine, say, the amount of lithium present in terms of the calcium content of the ash. Should greater precision be required than is obtainable by interpolation between the steps quoted, then standardised "spectroscopically pure" preparations of practically all the metals are available, and, by performing the necessary synthesis, a closer approximation can be obtained. An important feature of the method is that the technique employed ensures that the sample and the standard powers are brought into the same condition before the spectrograms are obtained.

Powders other than those for the analysis of vegetable ash are obtainable, *e.g.* one with a zinc base for metallurgical work, and it is obvious that in cases where a large number of tests have to be made on any one particular substance, a considerable saving of time will result if a "Ratio Powder" is specially devised for the purpose. It will be realised that it is essential for the success of such a method that a very comprehensive range of standardised preparations should be available. Examination of the published details shows that this

aspect of the problem has received a great deal of care and attention.

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THE CHEMISTRY OF SEA WATER IN RELATION TO THE PRODUCTIVITY OF THE SEA

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O what an endlesse worke I have in hand,
To count the sea's abundant progeny,
Whose fruitful seede farre passeth those in land,

. . . .

Then to recount the sea's posterity
So fertile be the flouds in generation,
So huge their numbers and so numberlesse their nation.

In the above quotation Spenser wrote more truly than he could have known. The lament would be a fitting one for an overworked specialist on the plankton, could he so word it. The ocean indeed is seeded with a dust of life; and though the powers of ten required in the count are smaller than those deftly handled by the physicist and astronomer, they are nevertheless quite imposing.

In brief, the sea is a solution of a large number of salts, subjected to solar radiation which is absorbed by myriads of microscopic plants whose numbers and minute size provide a suitable system for the absorption of certain of the salts which, though present only as traces, are yet essential for life. In the aggregate the mass of vegetable matter thus produced is very great. It is, of course, the food supply for all marine animals save the small minority supplied by the fixed algæ of the coastal zone.

In spite of the great quantity of vegetable life produced in the sea, the study of these forms has been neglected by British botanists with a remarkable degree of unanimity. At the Centenary Meeting of the British Association, the President of the Botanical Section, Prof. T. G. Hill, gave a summary of the development of botany for the previous century. In the first half of that period the morphology and systematic botany of algæ received attention, the plankton scarcely any, while botany itself was regarded as more or less an appendage of the medical school. Even after the botanical renaissance in

Great Britain, when the fresh-water phytoplankton received considerable attention, the marine phytoplankton continued in obscurity to constitute what is probably a total mass not very different from that of the aggregate of land plants. It is true that oral contact with sea water does not leave one with any vivid impression of its value as a nutrient, yet since the acres of the ocean have depth as well as superficial extent their productivity is quite considerable.

While fishes are caught in nets of large mesh and the zooplankton in nets of ever-decreasing mesh, it is necessary to work with silk nets having 180 strands to the inch in order to retain the finest of the plankton diatoms. There is always much uncertainty connected with quantitative plankton hauls with fine-mesh nets. One cannot be sure that the volume of water passing through the net is the same from one haul to another. Firstly, there is the difficulty of maintaining constant the necessarily very slow speed; it is hard also to keep the depth and the angle of immersion accurately the same; further, there is the question of clogging of the mesh, as by the gelatinous Phæocystis, which when present renders diatom counts quite unreliable. A more accurate, though very tedious, method consists in filtering known volumes of water, drawn from appropriate depths. Water has also been pumped up and centrifuged in a continuous stream by means of the Sharples and Foerst "super-centrifuges."

As an alternative one may study the phytoplankton quantitatively by noting the changes produced by it in sea water.

Alterations in the Alkalinity of Sea Water

Such changes can readily be demonstrated. A green alga, such as the common marine Ulva, or some filaments of any pond weed, such as Spirogyra, are placed in a jar, or test-tube, filled with water from the habitat of the species. To the water a few drops of an indicator are then added. Phenol phthalein, colourless or faint pink in sea water, may be used, or cresol red; for fresh water brom thymol blue, phenol red, cresol red, and phenol phthalein are suitable according to the original alkalinity of the water. On exposing to a bright light the colour of the indicator may be seen to alter in the water immediately surrounding the algal filaments. In time the change spreads and becomes intensified. The energy supplied by the light enables the algal cells to carry on photosynthesis, the carbon dioxide used up being replenished by the hydrolysis of bicarbonates, so that the water becomes increasingly alkaline.

Upon this reaction the late Prof. Benjamin Moore based a calculation of the annual phytoplankton crop in the neighbourhood of the Isle of Man. He assumed that the changes observed

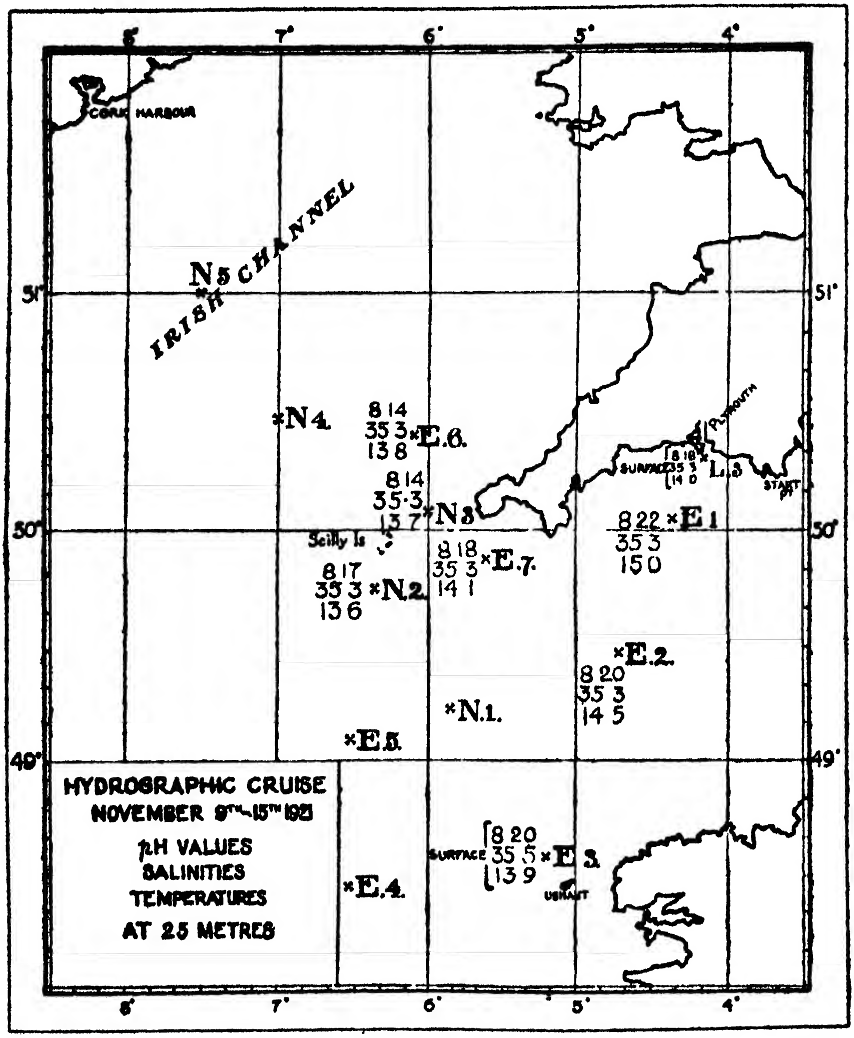


FIG. 1.—Hydrographic stations in the English Channel as worked by the Marine Biological Association's research ship from Plymouth.

at the surface extended to 100 metres owing to mixing and arrived at an estimate of two tons dry weight, or ten tons of moist plant per acre. On converting to the metric system these values become roughly 500 and 2,500 metric tons per square kilometre. The figures are somewhat too high, as the

depth assumed, 100 metres, is too great, since the deeper water is not affected as much as the surface.

The problem was studied in detail about ten years ago in the water of the English Channel. The seasonal changes in alkalinity were followed at a series of depths, both colorimetrically and by titration at stations ten miles outside the Eddystone and in mid-Channel. The carbon dioxide removed sufficed to provide 3 milligrams of a sugar, dextrose, per litre, all through the water column from surface to bottom. This may seem a small amount, but with a mid-Channel depth of 83·3 metres it gives 1 kilogram of dextrose under each 4 square metres of surface or 250 metric tons per square kilometre. Fig. 1 shows the hydrographic stations, E1 and E2, where these observations were made. It may be seen that

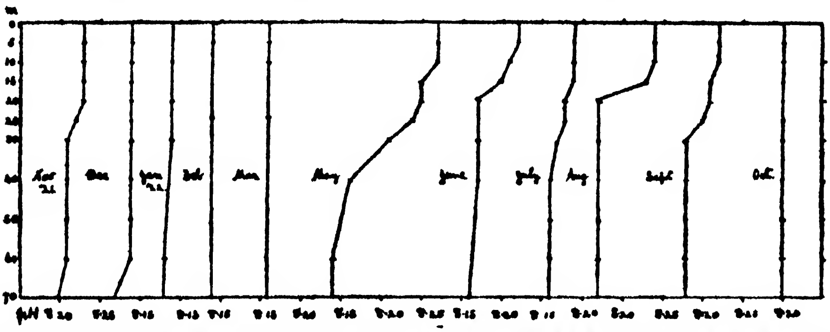


FIG. 2.—The ordinates are depths in metres. The abscissæ are pH values, arranged to read for each month separately. They refer to water samples taken at station E1 during 1921 and 1922.

they are far from land and not subject to shore contamination. The water at such stations is, moreover, typical of that over an extended area. Furthermore, study of the salinity has shown that in these regions, particularly at E1, there is no great movement of the water, so that from month to month the changes may be taken as being truly those in the same water, since we are dealing with a closed system. Occasionally, however, mass movements of water are detected and there is an inflow of more saline water from the south-west. Some of the hydrogen ion concentration measurements, expressed as pH values, are shown in Fig. 1, together with temperatures and salinities in parts per thousand.

In Fig. 2 it may be seen that the water has become noticeably more alkaline by March, though still uniform from top to bottom. By May, however, the upper layers have become markedly alkaline. The thorough mixing in July was rather an abnormal feature of this year, 1922, consequent upon wet and stormy weather.

In Fig. 3 the relationship between the changes in alkalinity of the sea water and the sunshine and duration of the day is shown. The alkalinity follows the sunshine, but does not

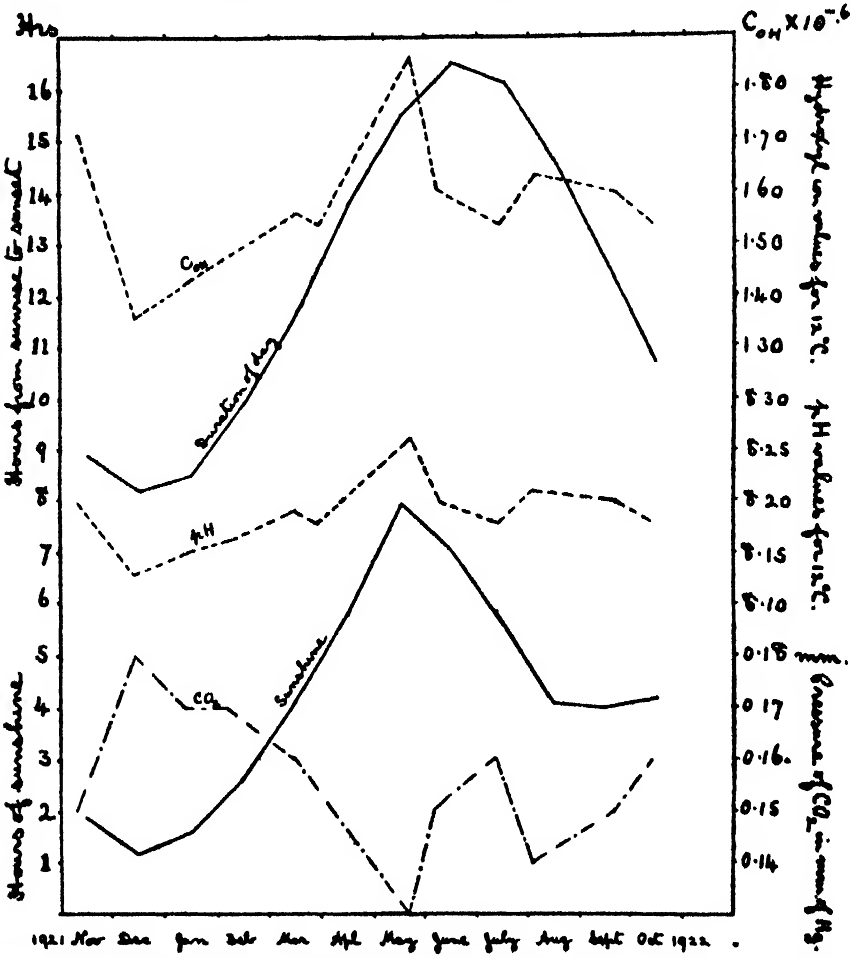


FIG. 3.—The left-hand ordinates refer to the two full-line curves, as marked. Those on the right relate to the dotted curves; the top one shows the alkalinity of sea water in terms of hydroxyl ion concentration, the middle curve shows the same plotted as *p*H values, and the bottom curve shows the corresponding carbon dioxide pressures as deduced by McClendon's method.

continue to increase with length of day as one would expect. The increase is indeed limited by another factor.

The Phosphate Concentration of Sea Water

If one takes a pure culture of a diatom and inoculates a sterilised flask of sea water enriched with the necessary salts,

there is soon a great multiplication of the diatoms so that the water becomes cloudy. Fig. 4 shows how the production of a great number of diatoms results in the complete utilisation of the phosphate in the medium. After that no further multiplication takes place. It was found that 1,000 million (10^9) diatoms used up 1·12 mg. of phosphate, reckoned as phosphorus pentoxide ; accordingly one gramme should suffice for 9×10^{11}. Data which will be presented later give 30 mg. per cubic metre for the annual consumption of phosphate in the water at

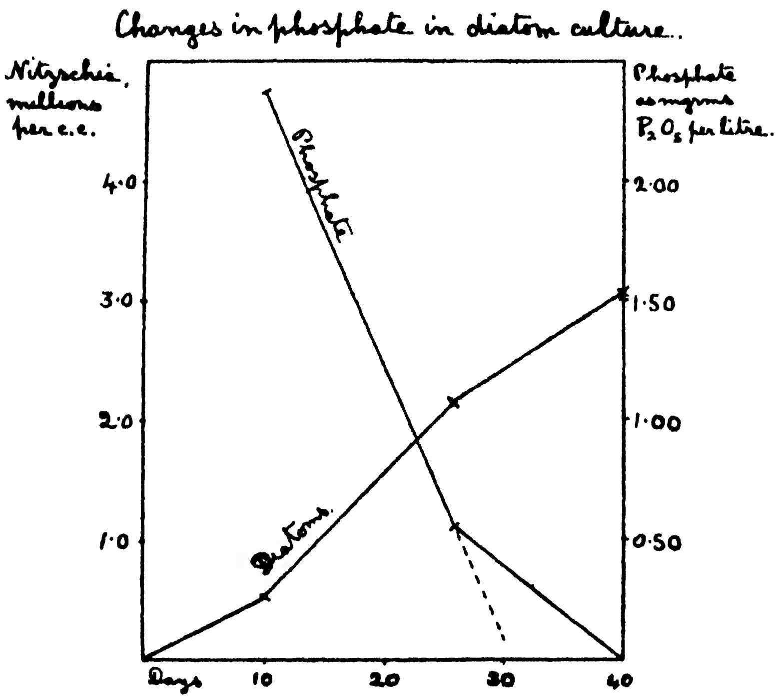


FIG. 4.

station E1, taking the average of 70 metres, surface to bottom. From this it follows that if all this were abstracted by diatoms each cubic metre of sea water would produce $26{\cdot}8 \times 10^9$ diatoms. As many as 30×10^9 of another species of diatom were found in a fresh-water pond, so these large numbers, as calculated, need not seem impossible.

It is of interest to consider what volume of water is stripped of its phosphate by one diatom, for since the diatom floats freely in the water it can only draw on a relatively limited volume. Making use of the data already given, it may be seen that each diatom has only to deplete one twenty-seventh part of a cubic millimetre. At the limit of detectable phosphate

concentration, 1 mg. per cubic metre, each diatom has to strip over one cubic millimetre in order to get enough phosphate, consequently the greater the dilution the slower must be the rate at which further diminution in phosphate proceeds.

Again, a knowledge of the phosphate consumption enables an estimate to be made of the minor limit of the annual phytoplankton crop. It is a minor limit because the phosphate may be set free and used over again, as is true also of the carbon dioxide. Calculated upon their wet weight the brown algæ contain 0·15 per cent. of phosphate. In the absence of direct analyses of diatoms the same figure may be taken as an approximation. On the basis of 30 mg. per cubic metre to a depth of 70 metres this gives 1·4 kilograms of phytoplankton under each square metre. If it be assumed that the carbohydrate content of the diatoms, reckoned as dextrose, amounts to 15 per cent. of the wet weight, the calculation previously given for the seasonal change in alkalinity gives an identical value, namely 1·4 kilograms, when recalculated for 70 metres depth instead of 83·3 metres. The exact agreement is fortuitous, but it lends support to the validity of the titration method, which is less exact than is the phosphate estimation. Thus the minimum value for the phytoplankton crop is 1,400 metric tons, wet weight, per square kilometre per annum.

During the war the late Sir William Thompson, Professor of Physiology in the University of Dublin, contributed to *The Times* a letter summarising what was known as to the yield of agricultural land under various crops and the production of live stock. From this it emerged that the yield of food per unit area was greatest when potatoes were grown, and that to feed pigs upon potatoes was the most economical method of producing edible flesh. Good land may yield twelve tons of potatoes, large and small. The weight of the green parts and stems is not included, but may be taken as roughly included if one considers average or poorer land. To produce an average pig of 170 lb. weight, giving 97 lb. of bacon, the weight of potatoes required is one ton and a half. These figures come to over 3,000 metric tons of potatoes per square kilometre, equivalent to 87 metric tons of bacon or 152 tons of pig or to 1,976 pigs per square kilometre. The bacon produced is not quite 3 per cent. of the potato consumed and the total weight of pig is slightly over 5 per cent. On this 3 per cent. basis the 1,400 metric tons of phytoplankton might produce 42 tons of animal food. It seems better to take 3 rather than 5 per cent., since the potato has a greater percentage dry weight. The pig, however, eats potato directly, whereas the marketable fishes are sustained only indirectly by diatoms. Firstly, small crustacea and other small animals feed on diatoms; then young

fishes devour the planktonic crustacea, largely copepods, and the larger fishes swallow anything of sufficient size to be worth

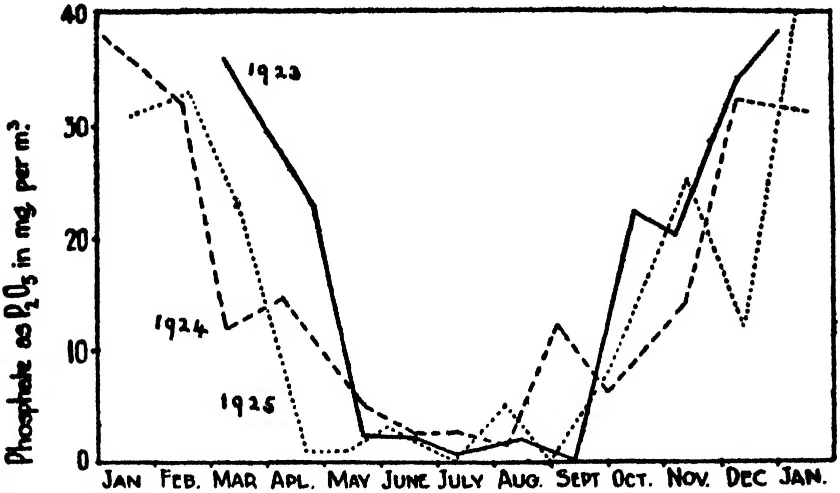


FIG. 5.—To show the phosphate concentration in the surface water at station E1 during three years.

while. We are in ignorance, however, as to whether this chain of food organisms is a more or a less efficient method of pro-

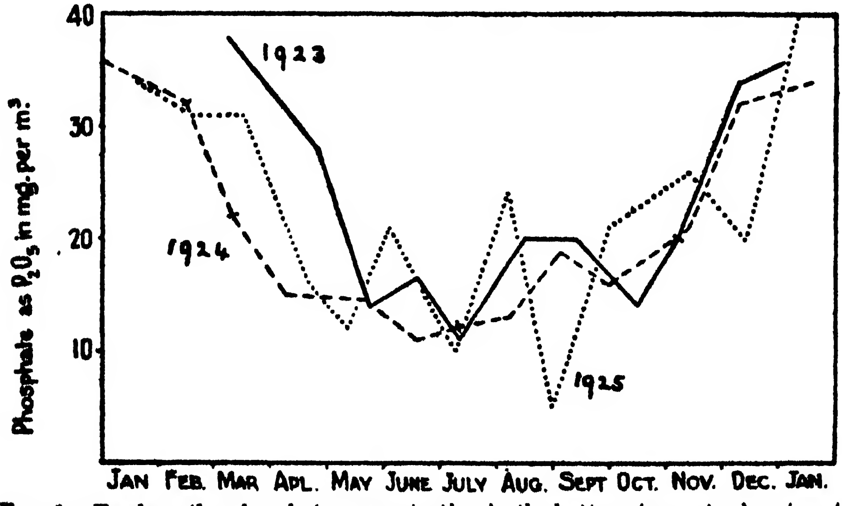


FIG. 6.—To show the phosphate concentration in the bottom (70 metres) water at station E1.

ducing vertebrate from vegetable food than is direct consumption, as in the case of the pig. The latter has to maintain a constant body temperature in excess of its surroundings,

whereas the marine animals are under no such obligation and should therefore, in each case, be able to produce more flesh for a given quantity of food.

Whatever the figure taken as the production of animal food per square kilometre—such as the 42 tons just mentioned—the aggregate of such substance removed each year from the sea is very great. Thus the Dependencies of the Falkland Islands have produced as much as a quarter to a half-million barrels of whale oil, and in the season 1915–16 as many as 11,792 whales

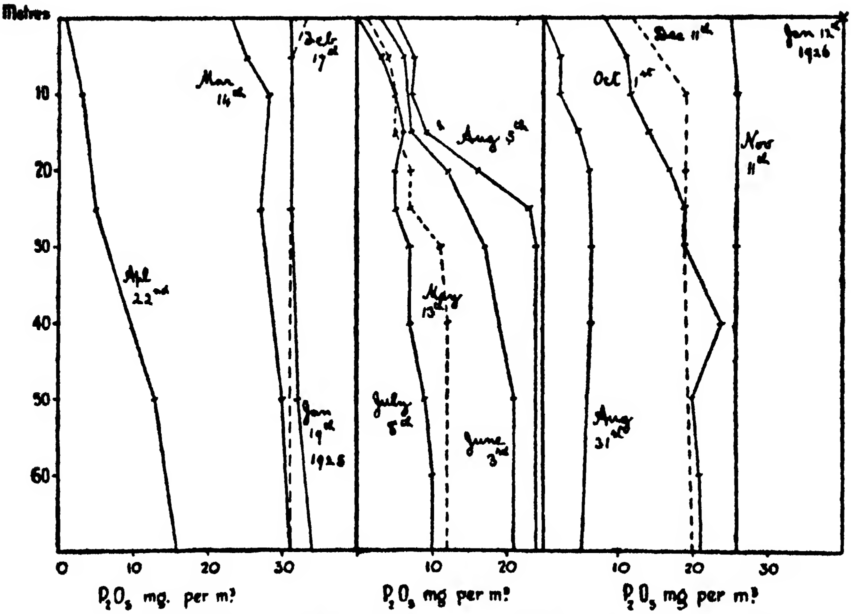


FIG. 7.—To show the concentration of phosphate at station E1, at various depths, during the year 1925. For the sake of clearness the data are presented in three groups—January to April, May to August 5, and August 31 to January 12, 1926.

were taken. It is estimated that the herrings landed annually in this country number 10^{10} and $1{\cdot}5 \times 10^{6}$ tons of fish are annually taken from the North Sea. Savage has calculated that 10^{9} herrings landed in 1926 at our East Coast ports would require as daily food no less than 300 tons of plankton, wet weight. Such fish are from three to six years old when taken, so their food consumption on life's journey must be quite considerable. Enough has been said at least to indicate that the consideration of the fundamental conditions underlying such a vast production of living matter is one worthy of serious attention.

The annual utilisation of phosphate has already been given as 30 mg. per cubic metre of sea water. It remains to show how

such a figure was obtained. Samples of water were taken, twenty miles out at sea, throughout the year and for a number of years. The phosphate content was found colorimetrically and is shown in Figs. 5, 6, and 7. It may be seen that as the year progresses the phosphate concentration becomes reduced to zero or near it at the surface and very considerably even at the bottom in such comparatively shallow water. Later on

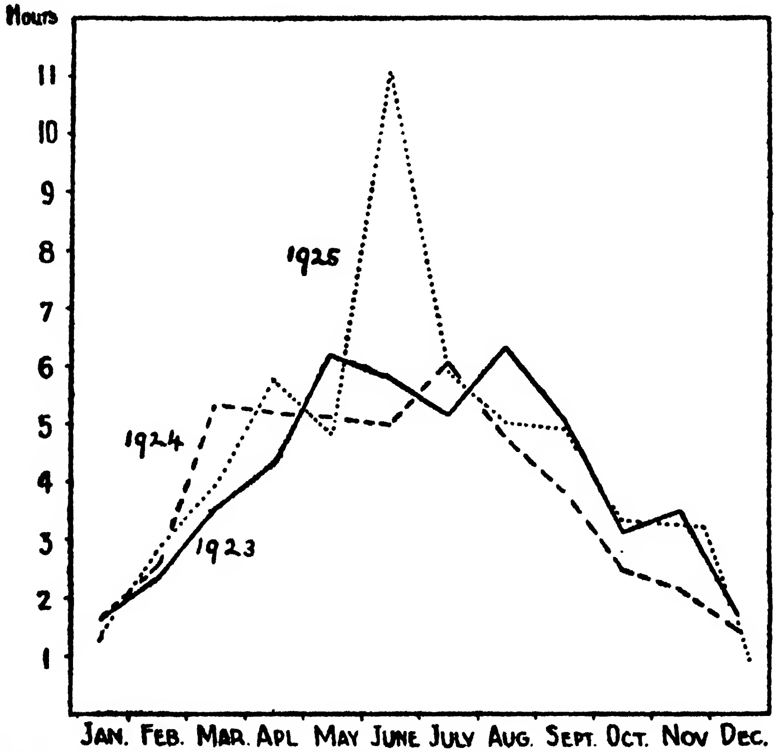


FIG. 8.—To show the mean monthly sunshine, plotted as for the 15th of the month, for the meteorological district England South-west.

the phosphate is set free again and so the cycle goes on. It is clear also that in spring the rapid decrease in phosphate does not occur at precisely the same time each year. In the years 1923–1925 the phosphate depletion runs in the inverse proportion to the spring sunshine, 1923, the latest year, having least sunshine as shown in Fig. 8. The abnormally great sunshine in June 1925 did not lead to any marked consumption of phosphate, for the surface water had already been depleted, but a comparison of the curves for June 3 and July 8 in Fig. 7 shows that the deeper water did become poorer in phosphate over that period. It may thus be seen why the water does not

become increasingly alkaline beyond a certain point. Even in the presence of adequate illumination the exhaustion of phosphate supplies sets a limit.

In Fig. 9 the data are set out somewhat differently to show

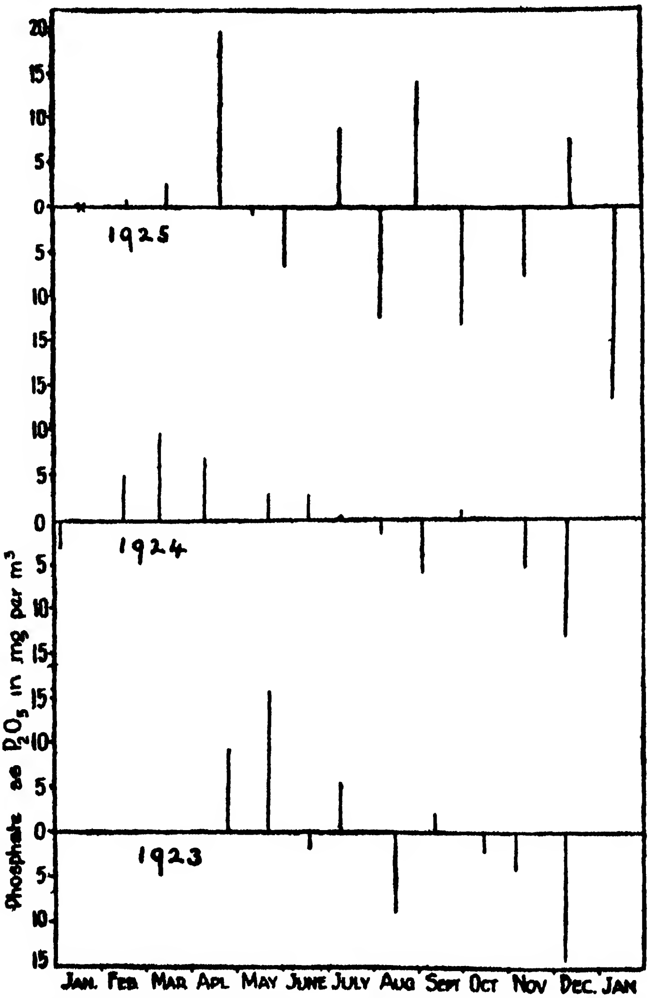


FIG. 9.—The utilisation of phosphate between successive dates of sampling is regarded as equivalent to phytoplankton production, as shown by perpendiculars above the zero line. Regeneration is plotted vertically below it.

periods of phytoplankton production above the horizontal line and periods of phosphate regeneration by the lines erected vertically below the horizontal. It may be seen that the years differed considerably.

By subtracting the consecutive values for the mean phos-

phate content of the water column at station E1 it is possible to arrive at an annual balance sheet as shown in Table I. It should be added that during the midwinter period the sea is relatively poor in phytoplankton around the British Isles, hence the phytoplankton crop calculated from the phosphate changes is an approach to a full measure, though always somewhat too low.

TABLE I

PHOSPHATE BALANCE SHEET FROM MARCH 1923 TO JANUARY 1926 INCLUSIVE, SHOWN AS MILLIGRAMS OF P_2O_5 PER CUBIC METRE, FOR THE 70-METRE WATER COLUMN AT E1.

Year.	1923.	1924.	1925.
Total observable consumption	33·4	29·5	53·8
Maximum minus minimum	29·6	28·3	26·9
Total observable regeneration	33·4	24·5	61·7
Gain in free phosphate, difference of successive maxima.	− 3·0	− 5·0	+ 8·0
Gain in free phosphate, consumption minus regeneration	0·0	− 5·0	+ 7·9

It may be seen from the foregoing that the lack of phosphate sets a limit to the further multiplication of the phytoplankton in summer and that in winter lack of adequate light energy limits their activity.

OTHER SALTS OF IMPORTANCE TO PLANT LIFE IN THE SEA

Nitrogen compounds are necessary for the phytoplankton, since free nitrogen cannot be directly utilised by plants. In the sea there is always present a small amount of saline ammonia, in the upper waters. Farther down it disappears or becomes much reduced. In the change, from ammonium compounds to nitrate, nitrite stands as an intermediate. It is accordingly found in the sea in small quantities only, and in surface waters less than 0·2 mg. per cubic metre may be present. In deeper waters, while ammonium compounds are being oxidised to nitrate, up to 30 or 35 mg. per $m.^3$ may exist. Nitrate, however, is the form in which nitrogen is mainly consumed by plants in the sea, though it seems probable that they can also use ammonium compounds directly. It has been shown by Harvey that the water is depleted of nitrate to about the same extent as of phosphate. It appears, however, that the phosphate is first used up, leaving a small quantity of nitrate. The gradual regeneration of phosphate, which appears to be set free as such or in labile organic compounds, results in a further depletion of nitrate up to the point of complete exhaustion in the upper layers. Phosphate then begins to accumulate in the deeper and in the surface water,

accompanied by ammonium salts, by nitrite, and finally by nitrate in the deeper waters. The mixing of the water consequent upon its autumnal cooling brings phosphate and nitrate together again and a fresh outburst of diatom activity ensues, limited, however, by the lessening power of the sun and by the fact that the continuance of a vertical circulation of the water tends to plunge the algal cells into the darker depths.

Since the outer walls of diatoms consist of silica, the presence

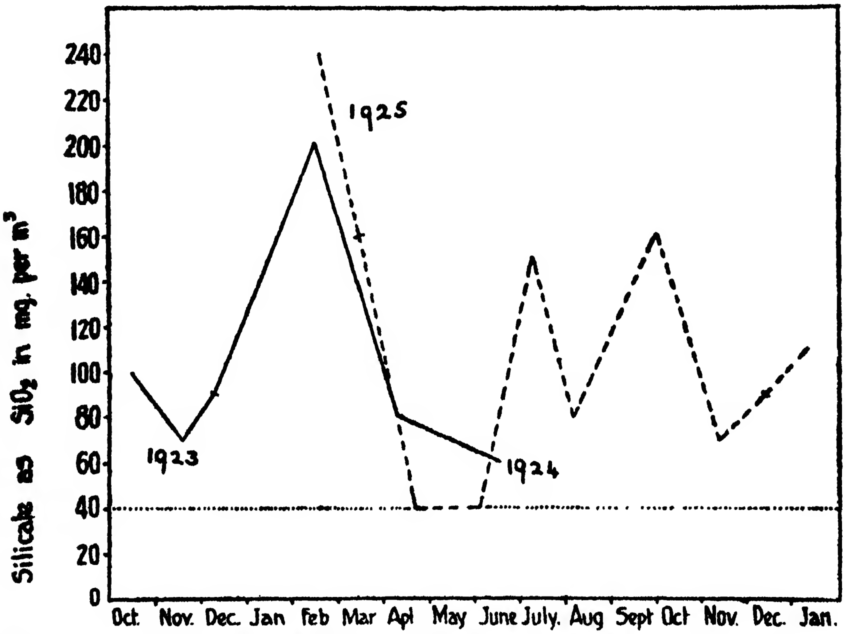


FIG. 10.—To show the seasonal changes in silicate in the surface water of station E1. The horizontal line at 40 mg. shows the limit at which silica could, at the time of analysis, be detected with certainty.

of silicate in sea water is important for them, though not for the gelatinous-coated Phæocystis or for the chlorophyll-containing Peridinians. Fig. 10 illustrates the behaviour of silicate, though it is uncertain whether its exhaustion is ever complete, since the method of analysis is not as delicate as is that for phosphate. In due course the silica appears to be redissolved and the silicate content of the sea water resumes its former level. The changes are not fully understood.

Most of the other elements required for plant life in the ocean appear to be found in excess. Iodine, for instance, present to the extent of 40 mg. per m.³ in various compounds has not as yet been shown to undergo marked seasonal variations. Arsenic, which is also taken up in small amounts, is

found in the form of arsenite, up to as much as 25 mg. of As_2O_3 per m.^{3} Iron seems to exist in sea water mainly in organic combination, and treatment with bromine water is necessary for its detection. The water appears to contain about 20 mg. per m.^{3}, but the iron cycle awaits fuller investigation, as does also the manganese cycle and that of copper, present in small amount, only 10 mg. per m.^{3} even in winter.

The Distribution of Phosphates and other Nutritive Salts in the Oceans

The analyses so far quoted relate to the comparatively shallow waters of the English Channel, in which the yearly cycle has been followed through a number of times. Analyses relating to deeper water have, however, become available, and serve to emphasise the limitation on plant growth imposed by the lack of adequate illumination; some are shown in Table II.

TABLE II

Analysis of Water from the Atlantic Ocean, taken between Lisbon and the Canary Islands in October.

Depth, Metres.	T.° C.	pH.	Mg. per M.^{3} Phosphate as P_2O_5.	Nitrate as N.	Silicate as SiO_2.
0	21·10	8·35	0	13	
20	21·00	—	—	6	220
50	20·01	8·35	0	6	
75	17·31	8·31	5	6	220
100	15·10	8·18	8	55	
200	13·86	8·11	22	100	250
300	12·25	8·12	44	170	
500	10·94	8·00	50	200	280
1,000	9·55	8·03	74	265	450
2,000	4·81	7·94	78	265	480
3,000	3·10	7·87	88	265	1,200

These results are in keeping with Nathansohn's hypothesis, put forward in 1906 and later tested extensively by Brandt, that the deeper waters are reservoirs of nutrient salts which only become available for absorption by plants when, owing to vertical mixing, they have been brought up to a well-illuminated level. The analyses made by a number of oceanographic expeditions have fully substantiated this hypothesis. As an example the experience of the staff of the R.R.S. *Discovery* may be quoted from Mr. A. C. Hardy's lecture to the Geographical Society in 1928. South Georgia is a narrow island, some 100 miles long, placed almost at right angles to the main drift of water coming from the west through the Drake Straits. The upwelling of deep water brings a continual supply of

nutrient salts, as typified by phosphate, so that off the south-west coast of the island diatoms, Chætoceros, Corethron, etc., were found in great abundance. These drift round the island, and in the slack water on the other side an abundance of crustaceans (Euphausians) was found feeding directly on the diatoms. The Euphausians are the main food of several species of whale, hence it comes that the region is a very rich feeding-ground for whales. This, combined probably with the geographical situation of S. Georgia, is the reason for the importance of this area as a whaling-ground.

Space forbids further citation of the interesting results obtained by other expeditions, nor is it possible to go into the problem of the measurement of submarine illumination. These may perhaps be dealt with in another article.

The author desires to thank the Marine Biological Association of the United Kingdom for permission to reproduce the figures from its *Journal* and for the use of the blocks.

ESSAY

HOW ANCIENT IS "HOMO SAPIENS"? (J. Reid Moir, F.G.S. F.R.A.I.)

When we pass in review the various races which make up the teeming millions of human beings inhabiting this planet, it is seen that, while in many ways, both physical and cultural, they differ from each other, they are all, nevertheless, variants of that widespread and prolific stock *H. sapiens*. If, further, we carry our investigation backwards in time, and examine the skeletons of people who lived during the period between about 40,000 years ago and the present day, we find that in every case the type is that of *H. sapiens*, while even the earliest examples are clearly as representative of " modern " man as is any person living in 1932. It thus becomes necessary to realise that, at an epoch separated from the present by some 40,000 years, *H. sapiens* was present upon this earth. But the matter cannot be left there, and as the idea of special creation no longer appeals to any seriously minded person, it is needful to ascertain what evidence, if any, exists which throws light upon the evolutionary origin and real antiquity of present-day man. The deposits in which the supposed most ancient skeletal remains of *H. sapiens* have been found are those containing the Upper Palæolithic industry of Aurignacian man. Immediately below these deposits is, in numerous cases in the French caves, a stratum in which are found cultural relics of an earlier and different type, associated with human bones of people differing profoundly, in their physical characteristics, from those of *H. sapiens*. These more primitive people are known as the Neanderthalers, or Mousterians, and are to be regarded as representing a form of *H. primigenius*. They had large and, in some respects, simian-like skulls, while their teeth and limb bones were quite unlike those of modern man. These differences are, in fact, so well marked that, even to a novice in such matters, it is obvious that the Mousterians and the Aurignacians represent two quite distinct branches of the human race.

Now, it is to be remarked that the lapse of time between the Mousterian epoch and that of the Aurignacian cannot well have

been, geologically speaking, very prolonged, and, even if it were physically possible for a Neanderthal type of man to develop into that of the Aurignacian—which most skilled anatomists deny—it does not seem credible that such a marked transformation could have taken place in the comparatively short period of time mentioned. When these aspects of the matter are considered, it would appear in the highest degree probable that the genesis of modern man must be looked for at some epoch older than that of the Mousterian, and the question at once arises as to whether—up to the present—this conclusion has been found to be supported by fact. There is, of course, no doubt that a number of claims to the discovery of human bones of the "modern" type, and of a pre-Mousterian antiquity, have been made. The best known—but by no means all—are dealt with briefly here, and it will be found that these refer to discoveries of the remains of *H. sapiens* in deposits belonging to the long cultural period—the Acheulean—immediately preceding that in which Mousterian man was distributed widely over Europe, the other, though less numerous, instances of the alleged unearthing of the bones of *H. sapiens* in still older beds being, for the moment, disregarded. It is, as has been already pointed out, an inherently improbable supposition (and one not to be made otherwise by the easy method of refusing to accept as reliable the discovery of any remains of man of the modern type in pre-Mousterian deposits) that *H. sapiens* first appeared on this earth in Aurignacian times, and it would seem, therefore, necessary to take due cognisance of any discoveries claiming, seriously, to support the conclusion that he is of pre-aurignacian antiquity.

Perhaps one of the best-known finds of this order is that made a number of years ago (1888) of parts of a human skeleton embedded in a loamy deposit of the 100-ft. terrace of the Thames at Galley Hill on the south bank of the river.[1] These remains—which clearly represent an individual of the modern type, were seen *in situ* by several reputable people. The bones rested at about 8 ft. from the surface, and appear to have been both underlain and overlain by stratified beds referable to Acheulean times, and therefore to a period older than that in which Mousterian man lived.

Of a like antiquity is the portion of a human skull in a fossil condition, found at Westley, near Bury St. Edmunds, Suffolk, in 1882. The specimen, which is preserved in the Museum at this place, was recovered from brick-earth, and asso-

[1] *Quart. Journ. Med. Soc.*, 1895, vol. LI, p. 505. The most accessible and illuminating account of this and similar discoveries can be found in Keith's *The Antiquity of Man* (first edition).

ciated with the remains of the mammoth and other mammals, and with Acheulean flint implements.[1] There is little doubt that the skull fragment is of the "modern" and not Mousterian type. In 1868, in a gravel pit in the Avenue de Clichy, Paris, on the right bank of the Seine, a remarkable discovery was made by M. Eugène Bertrand, a student who was in the habit of visiting excavations with a view to the collection of the fossil bones of mammals.[2] On the occasion of one of his examinations of the Clichy pit he was shown a human skeleton *in situ* in a loamy deposit at a depth of 17 ft. from the surface. The Clichy remains represent, without question, an individual of the type of *H. sapiens*, and, as it would appear, of the same geological age as those of Galley Hill and Bury St. Edmunds.

In 1914 Prof. Hans Reck, of Berlin, discovered, in the Oldoway ravine in what is now Kenya Colony, a human skeleton of the modern type, and buried in the contracted posture. Prof. Reck, the importance of whose discovery was not generally recognised owing to the onset of the war, has recently revisited Oldoway in company with Mr. L. S. B. Leakey and Mr. Hopwood, and these two investigators are convinced that Reck was right in claiming a great age for the skeleton he found. A most careful, and successful, examination has been made of the area where the Oldoway man was discovered, and has resulted in the recovery of very numerous bones of extinct animals from the human stratum, which has also been found to contain abundant examples of hand-axes of Late Chellean or Early Acheulean types. A full account of the recent work at Oldoway will, no doubt, be published in the near future, but the above are the conclusions which can be legitimately drawn from the reports which have appeared in *The Times* and *Nature*. Thus, it appears that the human bones of Galley Hill, Bury St. Edmunds, Clichy, and Oldoway represent discoveries of the remains of *H. sapiens* associated with Acheulean implements, and are to be referred to a period predating that in which Neanderthal or Mousterian man held sway in Europe. Further, it seems probable that, in the above instances, we are dealing with burials made from land surfaces existing in Acheulean times. If, as appears reasonable to suppose, it is indeed a fact that *H. sapiens* was in existence in the Lower Palæolithic epoch, and had then arrived at the stage of burying his dead in the contracted posture, certain matters of great, and revolutionary, significance arise for consideration.

The occurrence of the skeletal remains of *H. sapiens* at such an early period means that the origin of man must be looked for at a much more remote time than has been hitherto

[1] *Journ. Anat. and Physiol.*, 1913, vol. XLVI, p. 73.
[2] *Bull. Soc. d'Anthrop.*, 1868, ser. 2, vol. III, p. 329.

supposed. Moreover, this occurrence signifies that man, in company with certain other examples of animal, vegetable and insect life, is one of those creatures which, for some unknown reason, has not suffered marked evolutionary change over vast periods of time. For many of the mammals found with the remains of *H. sapiens* described have either become extinct or have been altered profoundly in their physical forms since those days. And it is clear that the evolutionary forces which have brought about these changes have been comparatively powerless in the case of man. Further, it would seem necessary now to realise that the human species was differentiated in very remote times, and that scattered about the world were living, contemporaneously, people of both *H. primigenius* and *H. sapiens* types.

To those, however, who appreciate the skill and thought which were required to make many of the Palæolithic and earlier flint implements—which exhibit great beauty of form, and are to be regarded as merely the indestructible elements of these ancient civilisations—the discovery of the bones of *H. sapiens* in pre-Mousterian deposits does not cause surprise. The long-held view that ancient man was simply a degraded savage limited in distribution, and of no great antiquity, is disappearing, and the past history of our race is, at long last, in process of being looked upon from a rational standpoint.

NOTES

The Gas-filled Relay (*S. K. L.*)

The recent developments in the larger types of grid-controlled mercury-arc rectifier and their applications to traction purposes were described in a note in the July 1932 issue of SCIENCE PROGRESS (p. 132). The theory and design of the grid-controlled rectifier, or gas-filled relay as it is called, are discussed in detail, together with descriptions of numerous applications, in an article by S. K. Lewer and C. R. Dunham in the *G.E.C. Journal* for May and August 1932. This article deals primarily with the hot-cathode type of controlled rectifier as distinct from the mercury-pool steel-tank type which is suitable only for extremely heavy loads such as are incurred in traction.

The mercury-vapour rectifying valve, from which the gas-filled relay has been developed, consists essentially of a heated electron-emitting cathode and a cool anode in an evacuated bulb containing a small drop of mercury to provide the necessary vapour pressure for the arc discharge. The gas-filled relay has, in addition, a third electrode in the form of a grid interposed between the anode and cathode. The function of the grid is solely to control the *starting* of the discharge. In the ordinary mercury-vapour rectifying valve, a discharge passes as soon as the anode potential is above about 15 volts. A sufficiently high negative bias on the grid of the gas-filled relay will withhold the discharge, even though the anode potential be raised to several thousand volts. On account of this property, this valve is sometimes called a thyratron (from the Greek *thyra* = *a door*). The reason for this controlling action is that the resultant field at the cathode is insufficient to produce cumulative ionisation necessary for the formation of the arc discharge. If the negative grid bias be reduced, a value will be reached at which the valve strikes. The ratio of anode potential to grid potential at this critical striking condition is practically constant over a range of values for most types, and is known as the "grid-control ratio."

After the discharge has been started, the gas-filled relay behaves like the two-electrode rectifier, since the positive mercury ions which are present in the discharge form a sheath

around the grid, and thereby neutralise its controlling action. In order to stop the discharge, the anode potential must be momentarily reduced to below about 15 volts. Ionisation then ceases and the valve is reset for control. This function is performed automatically once per cycle in the case of an A.C. anode supply. The instantaneous value of the anode potential at which the tube strikes is determined by the grid potential, so that the mean value of the rectified current may be controlled by means of the grid bias, hence the name "controlled rectifier." This valve may also be used in D.C. circuits, in which case suitable automatic resetting devices are required.

The simplest application of the gas-filled relay is as a trigger device. The power required to operate it is so small that it can be operated directly from a photoelectric cell. Such a combination as this finds almost unlimited application in industry where counting and sorting operations are required. A number of gas-filled relays have been used in a ring circuit capable of counting impulses up to the rate of 1,000 per second for the counting of α-particles. This trigger principle may also be utilised in the measurement of transient voltages or currents. An important case is the measurement of thermionic emission from heated filaments, where the passage of the emission current for anything but the shortest interval affects the filament temperature to such an extent as to render the measurement valueless.

As a contractor, the gas-filled relay may be used, in larger sizes, to make and break currents of 100 amperes or more many times a second without the use of heavy moving contacts. In arc-welding, the wear of the contacts is a serious problem, and a great saving has been effected by the use of the gas-filled relay.

The article discusses at some length the use of gas-filled relays in the "inverter" for the conversion of D.C. to A.C., but as this was described in the previous note referred to above, it will not be necessary to consider it here.

The operation of the gas-filled relay becomes most interesting when the controlling grid potential and the anode potential are alternating. It has already been pointed out that the mean rectified output current can be controlled by the value of the D.C. grid bias. With an alternating grid bias, a similar control can be effected by changing the phase relation between grid and anode potentials. In practice this is found to be a very neat method, since the phase change can be readily obtained by means of a varying resistance or capacity in the grid circuit. Typical examples of such applications are the precise control of the speed of a motor, or the temperature of a furnace. Another interesting type of application is the lamp-dimming circuit.

Here the rectified output of a gas-filled relay saturates the core of a choke in the lamp circuit and thereby controls the amount of illumination. This arrangement is highly efficient, since the relay may control ten times the amount of power consumed in itself. This is of great importance in theatre lighting.

The article contains a description of the new Osram Gas-filled Relay, type GT1, which has recently been developed in the Research Laboratories of the G.E.C. This is a comparatively small valve, the forerunner of larger types to be developed. It has an indirectly heated cathode, rated at 4 volts, 1·3 ampere. The anode rating is 1,000 volts peak at 0·3 ampere mean current, or 0·6 ampere peak current, and its grid-control ratio is 25–30. The voltage drop across the valve in ordinary operation, and in all valves of this character, is only about 15 volts, and is practically independent of the magnitude of the anode current. It is for this reason that the efficiency of the gas-filled relay is so high. Finally, it is necessary to see that the cathode is heated to its proper temperature before any anode current passes. This precaution, which must be taken with all hot-cathode gas-filled tubes, prevents destructive bombardment of the cathode by positive ions.

The Vitamins of Yeast (J. G.)

The division and subdivision of the vitamins which has been found necessary in order to explain experimental results has resulted in a scheme of classification in which there are not a few inconsistencies, and any communication which helps to clarify the position must be welcome. A recent paper, by J. C. Drummond and J. M. Whitmarsh, in the *Journal of the Institute of Brewing* (1932, **38**, 264), falls into this category so far as the "yeast vitamins" are concerned, for in addition to their own experimental work, the authors give an excellent tabular summary of present views on the subject.

It appears from this that there is evidence (though sometimes incomplete) for the existence of no less than five *B*-vitamins, viz.: B_1, the anti-neuritic vitamin of Eijkmann, the vitamin-*F* of Sherman, or the anti beri-beri vitamin. B_2, the anti-dermatitis, or anti-pellagra vitamin of Golberger, Sherman's vitamin-*G*, or Funk's vitamin-*D*. B_3, the "pigeon-factor," so-called because it differs from B_1 and B_2, in that it is not required by rats for growth, but is necessary for pigeons. B_4, which was originally confused with B_3, since it is required both by growing rats and pigeons. B_5, which is probably also required by rats, though the evidence for its existence is incomplete (cf. Peters, *Journal of State Medicine*, 1930, **38**, 20).

This summary is an indication of the complexity of the subject. Of the five vitamins mentioned, however, only B_1 and B_2 can be considered as separate entities, the existence of which have been definitely established. The authors have therefore confined their tests to these two factors, and have used young rats fed on a basal diet of caseinogen, starch, salts, and cod-liver oil free from either of the vitamins. B_1 and/or B_2 was added as required in the form of treated yeast (cf. Peters, *loc. cit.*) after several weeks, and the effects on the growth-curves were noted.

In confirmation of the results obtained previously, it was found that careful drying of yeast at 40–50° C. under reduced pressure does not appreciably destroy either vitamin, and that brewer's yeast is a much more valuable source of these vitamins than baker's yeast. The most important conclusion reached, however, is that certain yeasts (*e.g. S. logos*) will synthesise both vitamins when grown on an artificial dextrose-salt medium. On the other hand, a strain of *S. cerevisiæ* would only grow if "bios" (in the form of malt extract) was added to the medium, and there was then a decrease in B_1-content accompanied, possibly, by an increase in B_2. It is concluded that adsorption and absorption from the surrounding medium are largely responsible for the B_1-content of yeasts.

The Penetration of Solutions into Wood (J. G.)

The passage of solutions, particularly those containing electrolytes, through wood or other cellular compounds is of considerable importance, for not only does it shed an interesting light on the structure of the medium, but, so far as wood at any rate is concerned, it is of commercial significance in connection with the paper-pulp industry and furniture-staining. It is not surprising therefore to find several papers on the subject in the 1932 issue of the *Proceedings of the Canadian Pulp and Paper Association.*

R. Richardson (p. 49), for example, has studied the major phenomena which occur when White Spruce (*Picea Alba*) is immersed in 4 to 5 per cent. solutions of sodium hydroxide and hydrochloric acid, and in equimolecular mixtures of the two (*i.e.* 7 per cent. sodium chloride) from the points of view of the influence of the nature and concentration of the electrolytes and non-electrolytes present, the temperature, and the shape of the test-sample of wood. His results indicate that on immersion of the wood there is, firstly, a gradual diffusion of the whole solution into the substance (known technically as penetration) which is followed by, or perhaps proceeds simultaneously with, ordinary adsorption.

The author is careful to distinguish between the terms sorption, adsorption, and absorption. Sorption is used to indicate loss of substance from the surrounding solution, irrespective of the nature or mechanism of the process, and this may occur either by adsorption (*i.e.* by surface condensation), or by absorption, which corresponds with an even distribution of the sorbed material throughout the solid, whether as the result of solid solution or actual combination. There seems to be some real justification for these fine terminological distinctions.

J. W. Sutherland (*ibid.*, p. 52) has, on the other hand, attacked the problem from the point of view of the effect of pressure on the impregnation of the heart- and sap-woods of White Spruce, Red Pine, and Balsam, a chip of the sample being held in a clamp under suitable conditions of temperature and pressure, while a measured amount of liquid is passed through it. Curves show that the rate of penetration in unseasoned wood increases with the pressure at a greater rate than for seasoned woods, probably on account of the greater elasticity of the pit-membrane in the former case. Poiseuille's law is not followed once the membrane-pores are stretched beyond their elastic limit.

Temperature (50° to 150° C.) also increases the rate of penetration (of water) to an extent which is greatest at the higher temperatures; when the viscosity of the water increases, the pores become enlarged, and the resins and gums deposited on the membranes are softened. It may even be that gums and resins are removed under these conditions (*i.e.* above 70° C.), for the wood is rendered more permeable when it is eventually brought back to 20° C. Finally, it was shown that the rate of penetration of acid is greater than that of water at first, and then slower, the reverse being the case for alkali.

The Journal of Animal Ecology, Vol. I, No. 1, May 1932. (J. T. Saunders.)

The British Ecological Society, finding the numbers of papers dealing with animal ecology too great for publication in the *Journal of Ecology*, has decided to make adequate provision for these papers by the establishment of a new journal, *The Journal of Animal Ecology*, the first number of which has just been issued. This journal will publish papers dealing exclusively with animals (such as population and migration studies and allied problems) and with methods of research having reference primarily to animals. On the other hand, comprehensive biological survey papers, dealing both with plants and animals, will appear as heretofore in the *Journal of*

Ecology. One of the objects in starting this new journal is to centralise, to some extent, the widely scattered literature of animal ecology, and, with this aim in view, summaries and abstracts of relevant papers published in other journals, together with short notes and reviews, will be published in the *Journal of Animal Ecology*. There will be two numbers of the journal each year, published in May and November; the subscription is 30*s*. per annum (25*s*. for members of the British Ecological Society).

The first number of the *Journal of Animal Ecology* contains papers which relate chiefly to animal populations. The editor, Charles Elton, contributes an interesting paper on "Territory among Wood Ants (*Formica rufa* L.)," the observations which form the basis of the paper being made on an isolated community of these ants in a bird sanctuary in Hampshire. Each ants' nest had a distinct territory, containing certain trees and shrubs, on which lived almost pure cultures of aphides. These aphides were tended by the ants for their secretions. Trackways led from the nests to the trees harbouring the aphides, and it was noted that there was no communication between the trackways of neighbouring nests, nor was there normally any hostility between the communities, except for occasional destructive raids. One nest was observed to split into two, without any nuptial flight, and the original territory of the nest was divided into two. The main check on the Wood Ants was the Green Woodpecker (*Picus viridis*), but the ants themselves keep birds away from trees, and the owner of the bird sanctuary has since destroyed the ants' nests, as the ants were found to attack the nestlings of the Willow Wren.

The Food Investigation Board

The Report of the Food Investigation Board for the year 1931 records advances in the study of the scientific aspects of the storage of practically all varieties of food-stuffs—meat, fish, fruit, cheese, eggs, etc. Evidence of the general progress the work has made recently is shown in the increased importance now being attached to the more "subtle properties of freshness" in food. Though refrigeration has provided the general empirical solution of the problem of providing our food supplies, "our knowledge, especially on the biological side, is as yet wholly inadequate to ensure that these subtle properties of freshness are sufficiently conserved, even over comparatively short periods. This is a state of affairs," the Report states, "which research can remedy and it is, in fact, doing so."

Thus, increasing attention is being paid to the effect of

methods of preservation on the vitamins, whose presence in food-stuffs, as demonstrated by Sir Gowland Hopkins, is essential to life. For example, it has been shown that fresh sheep's liver contains an appreciable amount of vitamin C, but storage in the frozen state at – 19° C. for six days reduced the antiscorbutic activity, and the activity was further reduced when the storage was prolonged for six months. With Cox's Orange Pippin apples the deterioration of the vitamin C content was definitely more marked when stored at 10° C. than at 1° C., though in the case of Bramley's Seedlings, by far the most important English cooking apple, the difference at these two temperatures was not significant. There is only a very slight loss of vitamin C in Bramley's Seedlings frozen and stored at – 20° C. for several months.

A considerable amount of work has been carried out on the determination of vitamin A content of fish-liver oils. The variations from one species to another were found to be very great. Thus haddock-liver oil has only an average vitamin potency of 1·5 units, whereas that of halibut-liver oil varies from 150 to 750 units. An average cod-liver oil has a potency of about 10 units.

Considerable progress has been made in the work carried out in the experimental ship's hold at the Ditton Laboratory, which is constructed so as to enable experiments to be carried out on the control of temperature, humidity, and the composition of the atmosphere during the bulk storage of food-stuffs which react with their environment. The scale on which the work is done is such as to yield results capable of immediate practical application. Co-operation in this work with the Empire and the shipping industry has been deepened and widened by the formation of a Consultative Group, including representatives of the Dominions, India, the Colonial Office, the Empire Marketing Board, and representatives of the Shipping Lines.

The first stage of research relating to the possibility of importing mild cured bacon from the Southern Dominions has been completed. It has been shown that the transport of unsmoked, mild-cured bacon from Australia and New Zealand is impracticable under existing commercial conditions, since the fat becomes rancid after less than two months' storage, even if a temperature as low as – 10° C. (14° F.) is used. On the other hand, carcases of frozen pork can be successfully transported and used as pork or for the manufacture of bacon, and New Zealand now furnishes larger supplies of frozen pork than any other country in the world. Though mild-cured green bacon cannot be successfully transported from Australia and New Zealand under existing conditions, a search for new

methods is being made and encouraging preliminary results have been obtained with gas storage.

The possibility of drawing on Empire meat sources for the production of medicinal preparations is suggested in the Report, which states:

"At present, the Dominions supply only a negligible fraction of the animal tissues imported for the preparation of medicinal products. Provided certain precautions are taken, some of these tissues at least can be carried quite satisfactorily in a frozen or desiccated condition, and the possibilities of utilising the large supplies of animal glands available in New Zealand and Australia are being investigated."

The necessary manufacturing conditions can be complied with if, at the producing end, the collection of the glands can be organised and a method of quick freezing used.

The Report summarises as follows the progress on the preservation of fruit and vegetables by freezing.

"Work on the preservation of fruit and vegetables in the frozen state has continued. The method of preserving peas by freezing them at -10 or $-20°$ C., after partial cooking, has been improved, and the principle extended successfully to runner beans, potatoes and, less successfully, to asparagus. In the case of fruit, it was found that raspberries stored at $-10°$ or $-20°$ C. without previous heating were, when thawed, perfect in colour and flavour, and scarcely altered in texture. Raspberries thus lend themselves to storage, frozen in the raw state, better than any other fruit tried. On the other hand, certain fruits, like plums and cherries, if frozen raw, turn brown and develop an unpleasant flavour on thawing; but this can be prevented by heating the fruit in syrup before freezing. By this means, products similar to canned fruit, and suitable for distribution in the frozen state, or for canning out of season, have been obtained. Quick freezing does not prevent browning in plums and cherries, and offers no advantage over the ordinary methods of freezing in air with any of the vegetables and fruits mentioned."

Some interesting information is contained in the Report on the smoke curing of haddocks and herrings under properly controlled conditions. Haddocks require seven hours in a smoky atmosphere at from 80° to 90° F., with a relative humidity below 50 per cent., to arrive at a "finnan" finish. Under similar conditions herrings did not reach the cured colour in ten hours. To bring out the oily finish which the market requires, it was necessary to raise the temperature to 95° F. for a further hour, and then to 100° F. for a final hour.

"In ordinary commercial kippering," it is stated in the Report, "the temperature is judged by the smoker, who con-

trols it by opening or shutting the doors of the kiln to let in more or less outside air, thus increasing or decreasing the combustion of the sawdust. The smoker may also damp down by covering up the smouldering heaps with fresh or sometimes with damp sawdust. The length of the process, coupled with the uncertainty of a satisfactory result which attends "rule-of-thumb" methods of control, are doubtless the reasons why so many dyed kippers are nowadays to be found on the market. If attention were given to the installation of efficient methods of controlling temperature and humidity in commercial smoke-kilns, something approaching uniformity of high quality should be obtainable with the fully cured, undyed fish."

Experiments with the new method of "gas storage," already very successfully applied to Bramley Seedling apples, have been carried out with other varieties of apples, with pears, and with bananas. Experiments have also been made on the prevention of mould growths on oranges by the introduction of crystals of ammonium bicarbonate into the storage chamber. These crystals by dissociation maintain sufficient ammonia in the atmosphere to prevent fungal growth. Investigations have also been carried out on the packing of New Zealand apples, the wastage of bananas, and on the abnormal ripening in England of South African Kelsey plums.

Notes and News

The honours list published on the occasion of the King's birthday contained the following names of interest in scientific circles: *Knights:* Dr. Robert L. Mond, president of the Faraday Society; Prof. W. Wright Smith, Regius professor of botany in the University of Edinburgh. *C.B.:* Dr. C. V. Drysdale, director of scientific research, Admiralty. *C.M.G.:* Mr. H. E. Hurst, director-general of the Physical Department, Ministry of Public Works, Egypt. *C.B.E.:* Dr. Eleanor Constance Lodge, lately principal of Westfield College, University of London; Prof. R. G. Stapledon, professor of agricultural botany, University College, Aberystwyth. *O.B.E.:* Mr. W. G. Fairweather, director of surveys, Northern Rhodesia; Mr. G. Shearing, principal scientific officer, Naval Signal School, Portsmouth.

We have noted with great regret the announcements of the deaths of the following well-known scientific workers during the past quarter: R. H. Adie, of Cambridge, agricultural chemist; Dr. William Briggs, founder of the University Correspondence College; Dr. G. K. Burgess, lately director of the United States National Bureau of Standards; Sir W. W. Cheyne, F.R.S., surgeon; Dr. C. Christy, naturalist and collector; Prof. B. K.

Emerson, geologist ; Dr. H. T. Ferrar, geologist ; Dr. J. G. Garson, anthropologist ; Prof. J. W. Gregory, emeritus professor of geology in the University of Glasgow (by the overturning of his canoe in the Urubamba River, Northern Peru) ; Mr. A. M. Lea, entomologist ; Sir Thomas Legge, late Senior Medical Inspector of Factories ; Prof. G. Lusk, For. Mem. R.S., of Cornell, physiologist ; Baron Erland Nordenskiöld, Swedish ethnologist ; Mrs. Huia Onslow (Muriel Wheldale) plant biochemist ; Dr. W. Pember Reeves, at one time director of the London School of Economics ; Prof. Max. Rübner, of Berlin, physiologist ; M. Santos-Dumont, pioneer in aviation ; Mr. L. G. Sutton, seed specialist ; Prof. R. Thaxter, of Harvard, botanist ; Sir Richard Threlfall, G.B.E., F.R.S. ; Sir William Willcocks, irrigation engineer.

Dr. P. A. M. Dirac, of St. John's College, Cambridge, has been appointed to succeed Sir Joseph Larmor as Lucasian professor of mathematics at Cambridge, and thus, at thirty years, occupies the chair to which Newton was appointed at twenty-seven, and which has been held by Barrow, Airy, Babbage and Stokes.

Prof. J. E. Lennard-Jones, Melville Wills professor of theoretical physics at Bristol, has been appointed to the new Humphrey Plummer chair of inorganic chemistry at Cambridge. Prof. E. F. Burton has been appointed to succeed Prof. J. C. McLennan at Toronto, and the Rev. J. P. Rowland, S.J., succeeds the Rev. E. D. O'Connor, S.J., as director of the Stonyhurst College Observatory.

Lord Rutherford has been elected president of the Institute of Physics for the session 1932–33, Sir Samuel Hoare president of the British Science Guild, Prof. E. W. Marchant president of the Institution of Electrical Engineers and Prof. F. E. Weiss president of the Linnean Society.

The Council of the Royal Society has elected Sir Henry Wellcome to the Fellowship of the Society under the Statute which empowers it to elect "persons who . . . either have rendered conspicuous service to the cause of science or are such that their election would be of signal benefit to the Society."

Prof. F. E. Lloyd, Macdonald professor of botany in McGill University, has been elected president of the Royal Society of Canada for 1932–33. The Flavelle medal of the Society has been awarded to Prof. J. S. Plaskett for his work in astronomy.

Prof. William Bulloch has been chosen to succeed the late Sir David Bruce as chairman of the governing body of the Lister Institute.

Sir Aurel Stein has been awarded the gold medal of the Royal Asiatic Society for his explorations in Central Asia, and Prof. C. G. Seligman, of the University of London, has received

the second triennial award of the Annandale medal of the Asiatic Society of Bengal for his work on the anthropology of Asia.

Prof. G. P. Thomson, of the Imperial College of Science, has been awarded the Howard N. Potts medal by the Franklin Institute for his work on the wave properties of the electron.

The Council of the Royal Society has appointed Mr. C. N. Hinshelwood, of Trinity College, Oxford, and Dr. M. L. E. Oliphant, of Trinity College, Cambridge, to be Messel Research Fellows. Dr. W. Hume-Rothery, Magdalen College, Oxford, and Dr. A. J. Bradley, University of Manchester, have been appointed Warren Research Fellows.

Beit Fellowships for scientific research at the Imperial College of Science and Technology have been awarded to: Mr. R. M. Shackleton (University of Liverpool—geology); Mr. E. G. Jones (University College, Nottingham—spectroscopy); Mr. R. L. Rosenberg (University of Cape Town—quantum mechanics); Dr. O. B. Westcott (University College, Exeter—physical chemistry).

The chief societies interested in physical science in the United States have co-operated in the formation of an American Institute of Physics. The Institute will undertake the business side of the publication of the scientific journals edited by the co-operating societies and will maintain an information service for the Press.

A Chelsea Polytechnic Old Students' Association is to be inaugurated at a meeting to be held on November 4 next, on the occasion of the opening of the Polytechnic Extension by the Parliamentary Secretary to the Board of Education, Mr. H. Ramsbotham, M.P. Old Students wishing to be present at the meeting, or who desire particulars of the Association, should address communications to the Honorary Secretary, Chelsea Polytechnic Old Students' Association, Manresa Road, Chelsea, S.W.3.

The 12th Annual Report of the British Non-Ferrous Metals Research Association has just been issued. It is encouraging to note that despite the intense industrial depression this Association has received in subscriptions from its members a larger sum than in any previous year. The total income, with Government Grant, is over £25,000, and a very extensive programme of work is being carried out. The growth of the Association in recent years has been remarkable, but from the report it is obvious that great difficulties are still met with in financing the research and other work which has been planned. Considering the large extent of the field of industry which is covered by this Association, the present membership of 200 is much too limited. The tangible results which can be shown have been of great benefit to the engineering industries, but

those who ultimately benefit as users of metals apparently provide very little financial support to the Association, the subscriptions coming mostly from the metal manufacturers themselves.

A section of the report deals with the future outlook and claims that even greater success would promptly accrue from the more intensive co-operation of existing members and from a moderate and steady increase in the funds available to the Association. Amongst new materials which have been made available to industry by the Association's researches, the elastic "Stayput" copper for locomotive fireboxes, the new ternary alloys for cable sheathing and water pipes and the aluminium brass condenser tubes, are of outstanding importance. The practical nature of the Association's work is indicated by the researches it has in hand on such subjects as the Frost Bursting of Water Pipes, the Effect on Health of the use of Aluminium Cooking Vessels, Bearing Metals, the Tarnishing of Metals used for shop fronts, etc., and last, but not least, the searching enquiries which it is undertaking for its members on the improvement of the efficiency of industrial production. The report deserves the attention of all concerned with the production and utilisation of metals, and can be obtained from the Association's Headquarters, Regnart Buildings, Euston Street, N.W.1.

We print elsewhere in these notes a summary of the Report of the Food Investigation Board for 1931, from which it will be seen that really notable progress is being made in many of the larger problems which the Board set out to solve. This being so, we venture to suggest that some consideration should be given to work which would be of direct assistance to the small consumer. Two or three years ago the Safety in Mines Research Board published at a low price two excellent brochures intended for the instruction of the working miner, and, as a start, the Food Investigation Board might well imitate this procedure. For example, a booklet entitled *Safety in Food* might instruct the housewife how to test whether her food supplies are fit for human consumption. What, for example, is the implication of the iridescence so often observed on bacon, ham, and cold beef? How long will cream sold in cartons *undated* but stamped *For Immediate Use* remain fit for food? How long can one keep tinned foods—meats, fruit, fish, in the sealed tin and out of it? Why do we eat well-hung game with impunity and not beef and mutton in the same condition? How can one distinguish between a properly smoked kipper and the dyed variety—before cooking it? Why are preservatives forbidden, and what *cheap* methods are available to replace them? It should be realised that the consumer is concerned

with the quality of the food which he or she purchases and not solely with its quality as delivered to the wholesaler or retailer.

A pamphlet of the type contemplated above has just been published by the U.S. Department of Commerce with the title *Safety for the Household* (Circular of the Bureau of Standards, No. 397, sold by the Superintendent of Documents, Washington, D.C., price not stated—probably about 2s.). This treats in detail all the hazards which commonly arise in the home, classified as mechanical (falls, cuts, etc.), fire, gas, asphyxiation, electrical, lightning and miscellaneous (poisons, etc.). The conditions likely to cause accidents are discussed; methods for remedying them pointed out, and the appropriate treatment, if injuries are incurred, described. Moreover, "the general public, for whom this circular is written, is earnestly invited to correspond freely with the Bureau upon any phase of the subjects treated"! It is interesting to note that "the electrical wiring of residences is usually designed for use at 110 or 120 volts," and not 220 volts, as is, unfortunately, the common voltage in England, and that "house-wiring installations of recent date will have the circuits made up of white wires and black wires," the white wire being earthed. The use of electrical heating pads and quilts is deprecated, and stress is laid on the need for proper insulation of the electrical installation in bathrooms or in any other situation where the user may be wet or in contact with water. One point which is heavily stressed is rather surprising, namely, that once the gas supply is shut off by closing the main cock at the meter it should never be turned on again by the householder. In fact, "this precaution is so important that in some cities even experienced gas fitters are not allowed to turn on the gas unless actually in the employ of the gas company."

The *Annual Report* of the Council for Scientific and Industrial Research of the Commonwealth of Australia for the year 1931 should serve to dispel any doubts the tax-payer may have as to whether he is obtaining value for his money. Prickly pear has already been cleared from 3,000,000 acres of land, and an Act for the settlement of this land has been passed by the Queensland Parliament. Many millions of acres more will be cleared in the next few years. The apple export trade will benefit to the extent of £100,000 per year as a result of the Council's work on bitter pit. The banana industry has been re-established in New South Wales and Queensland, following the discovery of a method of controlling bunchy-top disease. The development of an effective vaccine against black disease in sheep will save £100,000 per year in Tasmania alone, and probably £1,000,000 in the whole Commonwealth. The dried-

fruit trade is making most successful use of the work carried on at the Viticultural Station at Merbein, and soil surveys have already saved the Government large sums of money in the Lake Albert district. Good progress is being made in the investigation of blue mould in tobacco and the buffalo-fly and blow-fly pests in cattle and sheep are being attacked. These items form a small part only of the work of the Council, but they will suffice to show how valuable it is to the Commonwealth.

A full account of the life-history of wood-worms is given in a booklet on *Furniture Beetles*, published by the British Museum (Natural History), Cromwell Road, S.W.7 (price 6*d*.). From the layman's viewpoint the most interesting section of the booklet is that dealing with the destruction of the pest. This is not easy even in raw timber and to free furniture or the woodwork of a house once it becomes infected is quite difficult, since most of the methods available involve the use of poisonous or inflammable liquids. Good results may, however, be obtained by brushing with benzene, terebene or carbon tetrachloride. The Common Furniture Beetle, *Anobium punctatum*, frequently uses old worm-holes for egg-laying, and these should therefore be filled up with bees-wax and turpentine or " liquid wood," tinted to the desired colour. The liquid should be applied about the middle of May at the time of pupation, and again at the end of July or early in August, when the young larvæ have hatched out. Treatment at these periods for a number of years in succession should result in the complete eradication of the worm. All insect life is destroyed if the interior of the wood be heated to 130° F.

The Bureau of Standards Journal of Research for June 1932 contains a very interesting paper by R. B. Kennard, describing an application of the Zehnder interferometer for the determination of the temperature of the air close to a heated surface. The research was undertaken to test the " film " theory of the transfer of heat from a hot surface to a gas in contact with it, and the results showed that the temperature distribution in the layer of gas close to the surface is not that indicated by the theory. In the May number of the same *Journal*, Heyl shows that the " knife-edge correction " for a pendulum eliminates itself in the case of a reversible pendulum carrying two planes which rest, in turn, upon the same circularly rounded knife-edge.

The Indian Journal of Physics, May 1932, contains an important paper by S. Bhagavantam, in which he presents, for the first time, the results of a complete study of the Raman spectrum of hydrogen. The relative intensities of the undisplaced spectrum line due to the Rayleigh scattering and of the various Raman lines were measured and the results compared

with the theoretical values obtained by Manneback from quantum mechanics. In certain cases there is a striking disagreement between the two values, but Bhagavantam and Raman show that this disagreement disappears if it be supposed that the photon behaves as a rotating particle possessing an angular momentum $\pm h/2\pi$.

Messrs. Adam Hilger, Ltd., have recently put on to the market a " Universal Double Monochromator " for use in investigations requiring powerful monochromatic radiations. The instrument employs the principle of double spectroscopic purification of the radiation. Wave-length setting and focusing are simultaneously effected for the whole instrument by means of a single adjusting drum engraved to read in wavelengths. The optical system is of crystalline quartz, and has an aperture of 6 cm. diameter. The range extends from 1850Å in the ultra-violet to 40,000Å in the infra-red, and means are provided for the attachment of a sensitive thermo-element.

Some ten years ago there was set up on Lough Derg in the River Shannon a Limnological Laboratory which did excellent work during its unfortunately short career. A first report was published by the Irish Fisheries Department in 1926, dealing with the seasonal distribution of the planktonic crustacea ; a second report by the same authors, R. Southern and A. C. Gardiner, appeared this year (" The Diurnal Migrations of the Crustacea of the Plankton in Lough Derg," *Proc. Roy. Irish Acad.*, vol. XL, Sect. B, No. 11, Dublin, 1932, price 1*s.* 6*d.*). This is a very valuable contribution to the much-debated question of the causes of diurnal migration, and is marked by thoroughness of methods and a judicial attitude in the interpretation of results. The observations were made continuously over a space of six days, six series of vertical hauls being made during each 24-hour period. Seven species were dealt with in detail, and where possible the material was separated out according to sex and size. In most forms there was the usual migration towards the surface during the night and a withdrawal towards the bottom in the hours of daylight. Large and medium-sized *Daphnia longispina*, however, tended to concentrate in the upper levels during the day, in contrast to the small forms of the same species, which came to the surface at night. In *Cyclops strenuus* the males always kept near the bottom. In all species considerable variations from day to day were found in the results. The authors rightly emphasise the need for observations lasting over several days at a time and repeated at intervals throughout a whole year ; it is also very necessary to separate out the sexes and growth stages, which may differ from one another in behaviour. The sources of error in the methods commonly used are still considerable, and

require further study. Discussing the various theories put forward to account for diurnal migrations the authors find that there is none to which exceptions cannot be found. " As soon as the sun sets, considerable migrations are undertaken, the direction of which is reversed with the return of daylight. We have seen, however, that such simple hypotheses as the conception of an optimum illumination, or the interaction of geotropism and heliotropism, may hold for some cases, but that they are not of general application. Either we must admit that the dependence of the observed movements on changes in the intensity of light is far less direct than would appear at first sight, or we must seek for explanation of the apparent lack of agreement between the results of different observers in the absence of precise information concerning both the environmental conditions and physiological condition of the animals themselves."

A. Farrington (*R. Ir. Acad. Proc.*, vol. XL, 1931, Sect. B, p. 109) discusses the origin of the peculiar Loo valley of Co. Kerry. It is a through valley leading from the head of the Kenmare ria to the Killarney plain. Evidence is given of the existence of an ancient base-level in the district, now situated at an elevation of 500 to 600 ft. O.D. It is preserved in the form of benches or flats, particularly in the Clydagh and the Roughty valleys. At the date represented by this base-level, it is concluded that the Roughty, which now turns westwards into the Kenmare trough across the open mouth of the Loo valley, followed the line of the latter northwards, and was joined by a considerable tributary from the south-west through the Derrincurrig gap. Uplift initiated a new cycle of erosion, during which subsequent streams were developed on the soft Carboniferous sediments troughed into the Kenmare syncline. This led first to the capture of the stream flowing eastwards through the Derrincurrig gap, and later, at a comparatively recent date, to the capture of the Roughty.

The paper is of interest in the comparisons it suggests with similar through-valleys in North Wales and Scotland, and also in its application of methods all too rarely used by workers in the British Isles.

In a short note (*Science*, vol. LXXII, 1930, p. 3) W. S. Glock treats of " The Dual Nature of Physiography," distinguishing between geo-dynamics—the study of the processes at work, and geomorphology—the interpretation of surface configuration or the results of the processes. There is little new in this, but it serves as an introduction to two further papers by the same author on " The Development of Drainage Systems " (*Ohio Journ. of Sci.*, vol. XXXI, 1931, p. 309. Summary in *Geog. Review*, vol. XXI, 1931, p. 475). In these

papers the dynamic view-point is developed in a useful and interesting manner. The development of drainage pattern is considered under the heads of initiation, elongation, elaboration, and integration. The emphasis throughout is on the streams themselves rather than on the valleys in which they flow, and, though the basic idea is not novel, its thorough working out is a distinct new contribution to the concepts and terminology of geomorphology. Briefly, the author describes a cycle, during the earlier stages of which the drainage pattern is complicated by the elongation of the initial streams and the growth of tributaries, while the later stages witness simplification through abstraction and piracy. An ideal diagrammatic summary of these stages of development is presented ; but it is supported by a selection of tracings of actual drainage patterns taken from the topographic maps of the United States Geological Survey.

ESSAY-REVIEWS

THE DOMAIN OF CHEMICAL EMBRYOLOGY. By C. F. A. PANTIN, M.A. Being a review of **Chemical Embryology**, by J. NEEDHAM, Ph.D. In three volumes. [Pp. 2021.] (Cambridge: at the University Press. Price £5 5s. net.)

PROBABLY the most serious question which faces those engaged in scientific work to-day is the enormous volume of publication. Each year sees fresh journals, and there seems no prospect of a limit. That this is the inevitable consequence of the active advancement of science is obvious. But it has serious consequences for the scientific worker, because it becomes increasingly difficult for him to be well informed of other sciences than his own—or even of work outside his own particular line of research. This is a very great danger, for it must tend towards the disintegration of scientific knowledge as a whole. It promotes narrow specialisation, and renders ever more difficult that infusion of new ideas from without which is the original source of great scientific advances. The problem is too serious to be left unheeded. The publication of abstracting journals is of only limited help, for without detailed knowledge of the facts and an estimate of the validity of the methods used, the conclusions of a research are ambiguous, and may be of little value.

But the main source of help for the research worker must be in the publication of comprehensive books. By collecting the available information in encyclopædic form it is made far more readily available. It is here that work such as Dr. Needham's *Chemical Embryology* is of immense value. He has succeeded in accomplishing a colossal task which few could undertake, and he has done it well. The book is not only exhaustive, but it is well arranged, and, possibly the most important of all considerations, it is well written. Many such works fail in that they become mere catalogues of unrelated data; this is certainly not true in the present case.

The book is in three volumes and contains some 2,000 pages, including a good index and nearly 7,000 references. In the first volume the author shows that chemical embryology may be considered a definite branch of science and traces the philosophical implications of its pursuit. This is followed by

an account of its historical origins. The rest of the book deals with every aspect of the subject. The unfertilised egg is first considered as a physico-chemical system, and it is refreshing to find a book dealing with the egg and embryo which commences by giving all the information at present available as to the physical and chemical nature of the system we are considering. Then follows a section on the conditions of increase of size and weight in the egg and embryo. One is impressed by the comparative lack of success obtained through the interpretation of growth curves by means of simple assumptions, which take no account of the fact that in the growing embryo the whole system is itself continuously changing in nature. Perhaps the most interesting section in the whole book is that " On increase in complexity and organisation." It contains, among other things, an excellent essay on the significance of axial gradients. The author demonstrates the impossibility of relating these to a generalised " metabolic rate," but draws attention to the great significance of the gradients themselves. Whatever the interpretation of these gradients may be, the theory put forward by Child, that gradients of differentiation exist, was one of the first theories in this field that led to predictable results.

The study of chemical embryology is itself still in an embryonic condition. To the reviewer nothing makes this more apparent than the fact that in a comprehensive work such as this only some four pages can be devoted to the relation of chemical embryology to genetics. One feels that in twenty years' time this section may indeed increase till it is comparable in size with the rest of the book. Never was there a clearer and more promising field for attacking the problem of the physical and chemical origins of growth and differentiation.

These sections conclude the first volume. The second volume deals more specifically with the biochemical aspects of the egg and of the embryo. Chapters on the heat production and rate of respiration of the embryo are followed by an account of its salt and water regulation. One of the most important conclusions which emerge from this work is that there is a progressive increase in control by the embryo of its internal physical conditions. This control unfolds itself concurrently with morphological differentiation. The development of such powers of regulation has played a vital part in the evolution of the more successful groups of animals, and the manner in which these powers are acquired during development provides a study of prime importance.

The most remarkable feature of development has always been recognised as the great and detailed complexity of the

adult organism compared with the physical simplicity of the egg from which it arises. Despite this the adult complexity of structure and function must in some way be reflected in the physical organisation of the egg. Its simplicity is deceptive, and has led investigators to treat it by methods applicable strictly speaking only to homogeneous systems in equilibrium. This is far from implying that such a method of attack is wrong and cannot yield valuable conclusions. In the absence of other data, it is essential, first, to determine how far the simple rules of homogeneous systems apply to the cell, and wherein they break down. This is true even though we have every reason to suppose the cell is a very complex system. To answer all such attempts by the assertion that cell activities are certainly so complex that such simple rules may not apply is to close the door to all further investigation. Provided that the inadequacy of hypothesis is always borne in mind during experimentation, it may yield very valuable results.

This is very well shown in the recent attempts to determine the *p*H and *r*H of the cell interior. The determination of *r*H presupposes that the system is homogeneous and in equilibrium. Attempts to determine the oxidation-reduction potential of the cell interior show that this is far from true within the cell. Photosynthesis with the production of oxygen may be taking place simultaneously with the active reduction of many dyes which cannot remain in equilibrium with a positive oxygen concentration. But such attempts have extended greatly our knowledge of oxidation within the cell, and we are left with a picture of a system in which intense reductions and oxidations may be simultaneously taking place more or less independently with no approach to equilibrium. It is work such as this that gives us the first insight into the physiological complexity which may underlie the apparent simplicity of the egg cell, and on which its powers of development and differentiation must ultimately depend.

The major part of the book consists of a series of sections each dealing comprehensively with the various aspects of the metabolism of the embryo. There are sections on carbohydrate, fat and protein metabolism—fields in which the author has recently made valuable contributions himself. Others concern the rôle of enzymes, hormones, and vitamins in ontogenesis.

One of the most interesting conclusions which emerge from recent work on the metabolism of the egg and embryo is that, concurrently with morphological differentiation, there are sequences of physiological processes. In the hen's egg, the major substances metabolised are successively carbohydrate, followed by protein and then fat. Nitrogen excretion takes place

successively through the stages of ammonia, urea, and uric acid production. The importance of such sequences is very great, and the author discusses them in a series of essays in the epilegomena. He suggests that there may be an explanation of these sequences in terms of recapitulation. This is a very interesting suggestion, but to the reviewer it seems a rather dangerous one. The data of chemical embryology are at present derived too exclusively from the Vertebrata : we owe too much to the mammal, the hen, and the frog, and not enough to members of other phyla of the animal kingdom. The danger of this stress upon vertebrate development rests in the fact it supports a tendency to consider members of other phyla as providing examples of a series decreasing in physiological perfection as their phyletic relationship to man becomes more distant. In the pig embryo various nucleases appear in sequence—none—guanase—adenase—xanthine oxidase. But one feels very uncertain of the argument that " There is thus some relation to phylogenetic order " on the evidence that guanase alone is found in the yeast cell, while in the mollusc *Sycotopus*, only guanase and adenase occur without xanthine oxidase (cf. pp. 1328 and 1642). A yeast cell, a gasteropod, and a mammal have traversed long and very different evolutionary histories. To-day each is adapted to its own very special environment. How can the physiological systems of two adult organisms phyletically unrelated to the vertebrata give evidence of the physiological phylogeny of a mammal ? At some future time, when the generalisations of comparative physiology are far more advanced than they are at present, it may perhaps be possible to deduce rules to which any organism must conform during its physiological evolution, but that time has certainly not arrived yet.

But though the reader may be tempted to disagree with some of the suggestions put forward at the conclusion of Dr. Needham's book, this only serves to show how stimulating these essays are. It is the great merit of this book that it is not only thorough, but that also the author has had the courage to attempt to weave the evidence into a consistent scheme from whence general conclusions may be drawn.

The book is very clearly printed, with good diagrams. Either because of the great care exercised in preparing it or because of the interest of the matter the reviewer has failed to detect any misprints. The price (£5 5*s*.) is not unreasonable for a work such as this, and, despite its large size, one hopes that the book will find its way to many individual biologists as well as to libraries. Few will not find new and interesting matter even in those fields which they consider to be especially their own.

TECHNICAL EDUCATION IN RUSSIA. By J. G. F. Druce, M.Sc., R.Nat.Dr. Being a review of **Industry and Education in Soviet Russia**, by J. G. Crowther. [Pp. xii + 94.] (London: William Heinemann, 1932. Price 7s. 6d.)

Although a more general interest is now being taken in Russian affairs, and consequently in the position of Science and Education in that country, Russia's vast area and its population of some 160 million souls are not always appreciated. Many parts of the Soviet Union possess rich mineral deposits which have hitherto been but little developed. The much-discussed *P'atiletka*, or Five Years' Industrialisation Plan, was an attempt to remedy this, and undoubtedly some such scheme was essential for the development of the country, if not for the very existence of the State, under whatever regime it was ruled. The success of the plan depends upon the labours of skilled engineers, chemists, and other qualified specialists, of whom there is an acute shortage in Soviet Russia to-day. This is not to be wondered at, when it is remembered that something like 80 per cent. of the people were illiterate before the war. Hence an extraordinary attempt has had to be made to produce a comprehensive educational system, and to train as many students as possible in the shortest possible time.

Great extensions in educational facilities have, of course, been made by other "new" countries. A similar development has, for instance, been necessitated in Czechoslovakia, where new universities and institutes have been opened, although here attention was first concentrated on primary and secondary education. In the extreme east of Czechoslovakia, in the province of Sub-Carpathian Russia, where in 1918 there were also 80 per cent. of the population unable to read or write, great progress has been made even by following orthodox methods. In Soviet Russia it would seem as though the authorities were anxious to impart a knowledge of, say, the calculus to pupils who were as yet unable to solve a quadratic equation.

Concerning Russia and Russian science, much has been written, but few writers are better qualified to explain the situation in that country than Mr. Crowther, who has paid recent visits to Soviet Russia, and really has first-hand knowledge. A little while ago his *Science in Soviet Russia* was published, and now his *Industry and Education in Soviet Russia* has appeared. In this book the author presents a clear picture of what Russia is doing to-day in the scientific and educational fields. He presents the facts with a very minimum of propaganda for or against either the political or the educational policies of the authorities. It will be seen that many costly mistakes have been made, but there can be no doubt concerning the magnitude of the efforts exerted by those carrying out the

educational programme, nor can the remarkable enthusiasm of the students be gainsaid. The students, be it noted, receive a "wage," and are therefore independent of parental support. No less than 40 per cent. of the technical education estimates are for students' emoluments, and in addition to this, the factories associated with each "technicum" make provision for further support.

Mr. Crowther explains that Soviet technical colleges are organised on the monotechnic principle. Polytechnics have been dissolved into groups of monotechnics, which helps to account for the large number of colleges with courses of university standard. The main classes of technical institutes are similar to the largest British technical colleges and the German *Technische Hochschulen*. Of these there are 188 now in existence, so that there is approximately one for each million of the population, a higher ratio than obtains in the British Empire.

The second type of technicum (of which there are 663) corresponds more closely to our polytechnics. There are also secondary schools with a definite technical bias, where secondary education is combined with specialisation in the needs of a certain industry, *e.g.* textiles. Besides these, there are the "Rabfacs," or "workers' faculties," for the education of adults from eighteen to thirty years of age. Students here are expected to leave at the end of four years with a knowledge higher than matriculation standard. In the actual methods of teaching Mr. Crowther states that he saw nothing startlingly new. Innovations were apparently nothing more than variations or extensions of methods in use elsewhere. He reports, however, that there were at least two college laboratories better equipped than anything of the kind in Britain. They were for the technology of artificial silk and machine tools. It appears that at times the population is being pitch-forked into new factories and institutes, and told to get on as best they can—an expensive method of teaching, but one which it is hoped will educate the students to their responsibilities.

Not the least valuable part of Mr. Crowther's survey of Russian technical education is that giving statistical information and the detailed syllabuses of the various types of college and technicum. If everything is carried out according to plan there should be rapid progress in technical and scientific education in Russia in the near future. Cut off from the rest of the world as she has been for the last decade or more, Russia is, nevertheless, not entirely independent of other countries. Specialists from America and Germany in particular have contributed towards the construction of new undertakings, whilst the purchase of essential equipment, both industrial and educational, has had to be made from abroad and paid for by exports.

The general economic depression over other countries must have its repercussions on Russia and inevitably tend to slow down developments there. In any case, however, Russia is so large and the Russian people are so numerous that the rest of the world cannot ignore them for long.

Principal B. Mouat Jones, of the Manchester College of Technology, who accompanied Mr. Crowther on the occasion of his last visit at the invitation of the Supreme Economic Council to advise on matters of technical education, has contributed an Introduction to Mr. Crowther's book. He points out that whether " the experiment in industrialisation on Socialist lines now proceeding in Russia turns out to be a complete or a partial success, whether one believes in or distrusts the political theory behind it, there can be no doubt about its importance and interest. One of the great obstacles to its success, perhaps the greatest, is the serious shortage of trained industrial personnel of all grades at present in Russia. The educational efforts being made to meet this shortage are immense ; a first-hand account of them is given by Mr. Crowther in this book, which can hardly fail to be of interest to any who are anxious to know what is going on in Russia. . . . The quite unprecedented magnitude and intensity of the effort cannot fail to produce results of importance."

REVIEWS

MATHEMATICS

Mathematical Tables. Vol. I. [Pp. xxxv + 72.] (London: Office of the British Association, 1931. Price 10s. net.)

It has been intended for some time to reissue as a collection the various mathematical tables that have been published from time to time by the B.A. Committee for the Calculation of Mathematical Tables. When it came to the point, however, it was found that many of the functions had gaps in the ranges covered by the arguments, and considerable additional computation has been needed to fill these in. Differences were not usually given in the original tables, but have now been provided. The tables are to ten or more figures, and interpolation is possible to the full accuracy of the tables themselves. The authors have been numerous, R. A. Fisher, L. J. Comrie and J. Henderson being specially prominent. Everett's interpolation formula is recommended, which avoids the need for printing any but even differences. The Bessel functions are reserved for a further volume. Perhaps the reviewer may express at this stage the hope that when they are done, the Airy integral, which is a most important function in its own right, may be tabulated directly and not by way of Bessel functions of order $\frac{1}{3}$.

Circular functions are given of angles in circular measure, hyperbolic functions, and the Ei, Ci, and Si functions. One misses in the Ei function a remark that the principal value of the integral has to be taken for positive values of the argument. The factorial function and the integrals and derivatives of its logarithm are given by A. Lodge and J. Wishart. The last table gives the Hh functions, which are simply related to the error function and its integrals and derivatives. The fundamental definition is

$$\mathrm{H}h_0(x) = \int_x^\infty e^{-\frac{1}{2}x^2}\,dx$$

In comparison with the standard notation this seems to have an advantage and a defect. The factor $\frac{1}{2}$ might have made it possible to read off directly from the table the probability of an error exceeding a given multiple of the standard error, without the usual application of the factor $\sqrt{2}$. But this cannot be done from the tables as printed, because $\mathrm{H}h_0(0)$ is not 1 but $(\frac{1}{2}\pi)^{\frac{1}{2}}$. Further, all these functions are connected immediately with the solutions of various problems in heat conduction, diffusion and viscosity, denoted operationally by $q^n e^{-qx}$, but the application would have been made much more direct had the factor $(2/\pi)^{\frac{1}{2}}$ been applied throughout.

Special mention must be made of the extraordinary care taken in checking and proof-reading, the whole of the tables having been stereotyped and proof-read afterwards.

Harold Jeffreys.

ASTRONOMY

Astronomy. By Forest Ray Moulton, Ph.D., Sc.D. [Pp. xxiii + 549, with numerous diagrams and photographic illustrations.] (New York: The Macmillan Company, 1931. Price 18s. net.)

Dr. Moulton has essayed the difficult task of providing in rather more than 500 pages a descriptive astronomy suitable for three distinct purposes. For

such an enterprise he has outstanding gifts, and it can be said without hesitation that here is a textbook eminently suitable for the elementary student, an admirable account of present-day astronomical knowledge calculated to appeal to the more general reader, and a handy reference volume from which reliable and up-to-date information can readily be obtained. This book will bear comparison with any of the numerous similar works issued from the press in recent years, and in some ways it transcends them all.

From the point of view of a textbook the arrangement is excellent, for the student is led by easy and natural stages from the earth beneath his feet and the well-known constellations above his head to the confines of the visible universe and the latest theories of its form and structure. Among other features, the book contains a useful set of star charts, short but clear descriptions of the instrumental equipment of the astronomer and his methods of work, adequate summaries of what is known about the sun, moon, and planets, and two final chapters, comprising some 130 pages, which are devoted to the stars, the nebulæ, and the sidereal structure. Special interest attaches to the chapter on the "Evolution of the Solar System," a subject in which the author is peculiarly at home. Laplace's Nebular Hypothesis and the fundamental points in which it fails, the Planetesimal Hypothesis of Chamberlin and Moulton, the Encounter Theory of Bickerton, and the Tidal Theory of Jeans are all clearly outlined, and their advantages and difficulties explained. The author obviously has a personal leaning towards a system of alternate decline and renewal, in which the sun first radiates away a portion of its mass and then renews its youth by passing through a region in space rich in scattered nebular or meteoric material. His preference, unlike that of Eddington, is for a cyclical and eternal system, ever changing, but, on the average, always the same, though he fully recognises that dynamical and other difficulties make the formulation of such a theory at present unsatisfactory.

Dr. Moulton has the great advantages of a comprehensive knowledge, a long experience of teaching, and a sound and conservative judicial mind. His insistence on the necessity for proving all things, and for regarding very little of our present knowledge as absolute and final forms a welcome contrast to the dogmatic statements of some writers concerning their own pet hypotheses, investing them with that ultimate truth for which man ever strives, but to which he never attains.

The value of the book to the student is increased by the numerous lists of questions offered for his solution, and the suggestions for further reading and reference. It is well illustrated, bound, and printed, and there is an adequate index.

There are numerous small errors which have evidently escaped attention during the correction of the proofs. Examples of these may be found on p. 65, ll. 17 and 34; p. 93, l. 12; p. 128, l. 8; p. 171, l. 9; p. 234, l. 11; p. 337, l. 21, etc., etc.

R. W. W.

Signals from the Stars. By George Ellery Hale. [Pp. xx + 138, with 56 illustrations.] (London: Charles Scribner's Sons, 1932. Price 7s. 6d. net.)

During recent years Dr. Hale has contributed numerous scientific articles to Scribner's and Harper's magazines which have been collected, modified, and revised, and issued in book form under arresting and attractive titles. The present volume is the fourth of the series, and deals with the development and further possibilities of the telescopes and their accessory instruments by which the signals from the stars are received and interpreted. Dr. Hale's scientific eminence, his literary gifts, and his clarity of style are too well known to need further emphasis. The achievements of the Mount Wilson

Observatory and the author's own two instruments, the spectroheliograph and the spectrohelioscope, naturally receive special attention. The last chapter, describing the plans for the construction and location of the projected 200-inch reflector, is full of encouragement for the ultimate success of this great enterprise. It is not easy even to imagine the possibilities of such an instrument, fully ten times as powerful as the Hooker 100-inch, erected on an ideal site, and used in combination with all the chemical and physical research equipment of the California Institute of Technology. An increase in the speed of photographic plates will be as advantageous as a further increase in telescopic aperture, and improvements in auxiliary instruments such as spectrographs, photoelectric cells, and bolometers are equally necessary for extending the range of the observations. Dr. Hale's projected alliance between the astronomer, the engineer, the optician, the physicist, and the chemist is certainly fraught with great possibilities, and his book will kindle enthusiasm in both scientist and layman.

R. W. W.

PHYSICS

The Kinetics of Homogeneous Gas Reactions. By L. S. KASSEL. [Pp. 330.] American Chemical Society Monograph. (New York: The Chemical Catalogue Company. Price $6.50.)

THIS is a book for specialists in chemical kinetics rather than for readers not already familiar with statistical mechanical reasoning and an outline of current views of the molecular mechanism of chemical change. But now that the book exists it provides so much valuable material that research workers in this subject will probably agree that for them it has created its own necessity.

Besides a short appendix on the defunct Radiation Theory and a table of heats of dissociation of molecules (with authorities) which have been used consistently in recalculations of experimental data in the text, the book consists of two parts: " The plan which has been adopted is to separate the theoretical treatment almost entirely from the experimental data. This theory is presented in Part I, which occupies a little less than half of the entire book. It is preceded by an extremely condensed treatment of those portions of statistical mechanics which are most frequently used in the remainder; for the complete understanding of this first part, however, a more thorough knowledge of statistical mechanics than can be obtained from the first chapter will probably be necessary. In the second part all of the experimental data available have been discussed. These data are grouped according to the general type of reaction involved; in each case, an attempt has been made to state in the simplest possible language the results of the corresponding theoretical treatment. It is intended that this second part shall be complete in itself. Throughout the entire book a critical attitude has been adopted . . .; it is, of course, an essential duty of such a summary to point out those directions in which progress is most needed."

The experimentalist will appreciate the first part of the book for the discussion of recent theoretical papers which are rather scattered in the literature; especially the sections describing the London-Polanyi-Eyring application of quantum mechanics (" The presentation which is given here does not follow exactly that of London; this is partly because London has never published a really full account, and partly in an effort to arrive at a method which will be clearer to the chemical reader; it must be supposed, of course, that even he has some knowledge of quantum mechanics ") and Dr. Kassel's own work on the statistical consequences of making more detailed assumptions about the incidence of quantum restrictions in unimolecular changes, and of taking into account the force fields of real gases in calculating the triple collisions in kimolecular reactions. It must be said, however,

that the experimentalist may feel doubtful whether the quantitative results at present obtainable by direct measurement of gas-reaction rates will stand the strain of deciding for or against the hypotheses made. The author is critical throughout, but relatively more so of the theories than of the experimental results to which they are applied.

A great deal of careful work must have gone to the preparation of this book, which will be appreciated by all who are interested in reaction kinetics. At the present rate of publication in this field, the task of keeping the book revised will be an unusually heavy one, but it is much to be hoped that the author will find time for this in the future.

B. T.

The Physical Significance of the Quantum Theory. By F. A. Lindemann, Professor of Experimental Philosophy in the University of Oxford. [Pp. vii + 148.] (Oxford: Clarendon Press, 1932. Price 7*s.* 6*d.* net.)

The reviewer was present at a recent after-dinner meeting when a well-known mathematical physicist was asked to name the books which he would recommend to students of physics and chemistry, who, while not being highly trained in mathematics, wished to obtain a sound working knowledge of the new wave mechanics. He promptly recommended C. G. Darwin's *New Conceptions of Matter* as a first introduction, Mott's *Introduction to Wave-Mechanics* as a mathematical introduction, and, finally, a book by Frenkel, of which an English edition is shortly to appear, as a more profound mathematical treatise on the subject.

The reviewer heartily commends this list, which should meet the requirements of nearly all chemists and physicists. He would, however, most definitely recommend the addition of Prof. Lindemann's book to the list, for, while it has not much in common with the other books, it does present a point of view which is of extraordinary interest, and, moreover, it presents it in such a way that on reading it one obtains a feeling analogous to that experienced on taking a "breath of fresh air."

The main object of the *Physical Significance of the Quantum Theory* is to rob the theory of much of the air of mystery which surrounds it. The quantum theory has been described as one of the fundamental laws of governance of the Universe, and he finds it particularly interesting that, in Prof. Lindemann's view, the difficulties which we experience with the theory arise simply because our mental conceptions of space and time are insufficient for the adequate description of reality.

Prof. Lindemann shows that our difficulties have arisen because it has been customary to employ one conjugated co-ordinate and to neglect the other. Thus, in forming a conception of distance, we fail to take into account the recoil produced by the measurement upon the object whose distance we measure. He particularly emphasises that the principle of indeterminacy, a simple generalisation deduced from experiment, really means that the measurement of any one co-ordinate automatically produces an uncertainty in the conjugated co-ordinate, such that the product of the error in the co-ordinate measurement and the error contained in the conjugated co-ordinate has the definite universal value h, equal to $6{\cdot}545 \times 10^{-27}$ erg. sec.

In the light of this principle he examines the classical laws of physics, the statistics of Einstein and Bose and of Fermi and Dirac, the Planck oscillator, the hydrogen atom, and the periodic system. Finally, he deals with quantum and wave mechanics. The whole treatment is most stimulating; it is characterised by a wonderful freshness of outlook, and it is heartily commended to all interested in the quantum theory, even though many readers will by no means accept the outlook in its entirety.

L. F. B.

Photoelectric Phenomena. By A. L. Hughes, D.Sc., Professor of Physics, and L. A. Du Bridge, Ph.D., Assistant Professor of Physics, Washington University, St. Louis. [Pp. xii + 531, with 323 illustrations.] (London: McGraw-Hill Publishing Co., 1932. Price 30s. net.)

Although several excellent treatises in English have recently been published on the technical aspects of photoelectricity, it is some time since an English treatise dealing with its more academical or theoretical aspects has appeared. During this same time the output of experimental work, often directly inspired by the requirements of practical applications, has become enormous, and the new theories of the conduction of electricity by metals have also made further advances in the theoretical treatment of photoelectricity possible. Moreover, many phenomena of photoelectric origin were more or less ignored by the earlier writers, possibly because they represented a confusing assortment of facts, and possibly because they were but little understood, and it is now expedient that they be properly summarised. Consequently, the authors need offer no apology on the appearance of their book, the writing of which evidently gave them much pleasure.

They have first-hand knowledge of very many of the phenomena and of the experimental technique which they describe, and it is one of the most pleasing features of their book, that they include so many valuable hints on experimental technique, such as are not readily accessible in books of reference or even in original papers. These hints should serve as a very helpful guide to those about to commence research in photoelectricity. In like manner, the valuable data collected in the book should be of much assistance even to experienced workers in this field.

The authors' statement of the fundamental laws of photoelectricity is adequate and concise, and it is wisely emphasised that photoelectric phenomena must be divided into three classes, *viz.* surface and volume photoelectric effects and photovoltaic effects. Their account of the experimental verification of Einstein's fundamental equation contains a description of Olpin's work, published in 1930.

Particular attention is paid to the problems associated with the photoelectric threshold, and to the description of recent experimental work showing the definite agreement which exists between the thermionic and photoelectric work functions for a given surface. The effect of temperature on the total photoelectric sensitivity, on the maximum energy of emission, and on the photoelectric threshold is fully discussed. An interesting graph showing the values of the photoelectric threshold for the elements of the periodic system is reproduced, for in this connection Du Bridge has done some very useful work.

The selective photoelectric effect is given a prominent place in this book. The work of Fleischer on the correlation of polarisation selectivity with spectral selectivity is described, whilst the work of Ives and of Suhrmann on the selective effect with very thin films also receives adequate notice. The purely optical explanations of the selective effect given by Ives and Suhrmann in 1921 are outlined, together with Fowler's wave mechanics treatment of the problem, in which a particular form of potential barrier is assumed to exist at the sensitised metal surface.

The authors indicate that, as they do not consider themselves theoretical physicists, they include a chapter on modern theories of the photoelectric effect in their book with a certain amount of trepidation. This can only be considered as evidence of undue modesty on their part, for they have succeeded in producing an extraordinarily concise and interesting account of the most recent theories of the conduction of electricity by metals and their bearing on photoelectric emission. This account is remarkably up-to-date, for some its sections, *viz.* on the effect of temperature on photoelectric emission, contain matter which was summarised for the first time in the Recent Advances in the last issue of Science Progress.

The ionisation of gases and vapours by ultra-violet light is a subject which is very inadequately treated in most books on photoelectricity; here it receives proper attention. A similar remark applies to the subject of photoconductivity, in which the authors particularly stress the importance of the work of Gudden and Pohl, who were the first to separate photoconduction currents into primary and secondary currents, the latter being due to a reduction in the resistance of the irradiated material as a result of the flow of a primary current produced by the liberated electrons. In this connection it is interesting to note that the effects observed with selenium are almost entirely due to secondary currents, and that primary currents can only be effectively examined by making experiments on single crystals of the red insulating variety of selenium. Of more than fifteen hundred papers on the properties of selenium, only one has so far dealt with the separation of the effects of primary and secondary currents.

Photo-voltaic effects, such as those produced by the illumination of a cuprous oxide cell, are described in detail. So, too, are the photoelectric effects observed with non-metallic substances, and the photoelectric effects observed with X-rays and γ-rays. Practical applications of photoelectricity are only briefly treated, in view of the fact that several good books, which deal with these matters, already exist in the English tongue.

This book is exceedingly well annotated , references to English and foreign works are fully quoted and appear to be well balanced. Indeed, the authors clearly show that very little work on photoelectricity can have escaped their notice. Their work is a first-class treatise and one which is likely to be regarded as indispensable for some time to come.

L. F. B.

Cours d'Électricité Théorique (Vol. III). By J. B. Pomey. [Pp. 315, with 41 figures.] (Paris: Gauthier-Villars & Co., 1931. Price 90 frs.)

This book is the third of a series of volumes devoted to the mathematics of electricity and magnetism, special attention being given to applications in electrical engineering. The method of treating a number of the subjects discussed is distinctly novel and the author is to be congratulated on his astonishing versatility. He soon gives ample evidence to show that he is not only an expert mathematician, but also an electrical engineer of wide knowledge and experience. With these qualifications, he is able to make many of the problems which have been previously investigated mainly by experiment yield to mathematical treatment in a most enlightening way. There is, however, one criticism to which the author has laid himself open. In deriving and applying some of the mathematical relations it is, of course, necessary to make certain limiting assumptions, and one cannot help feeling that these assumptions are sometimes not kept sufficiently in the forefront of the argument, with the result that the unwary reader may be inclined to draw conclusions which are not altogether justified.

Although a good deal of the work can be found in original papers, this is the first time that it has been collected together and correlated for publication in book form. Without going into details, the following outline will give an idea of the outstanding features of the treatise.

The opening chapter is devoted to a re-statement of the general equations to the electromagnetic field. This is followed by an analysis of the most important properties of electromagnetic waves, the conditions for radiation from different aerial arrays used in radio communication, and a discussion on dielectric polarisation. Then comes a section introducing the principles of tensor calculus and some appropriate applications in the sphere of relativity. The general theory of the telephone cable is dealt with next: the calculation of the primary and secondary constants; distortion, its causes and its remedies; the elimination of interference between adjacent circuits and the theory

of artificial lines. A discussion on methods of producing and maintaining high-frequency oscillations follows, special attention being given to the thermionic valve oscillator. Finally a chapter is devoted to a somewhat varied collection of electric circuit problems arising in connection with telephone and telegraph systems.

The book is unquestionably a most useful compendium of a large range of mathematical researches. It can be recommended with confidence for close study. The diligent student will find in it many interesting ideas and valuable suggestions. One's only regret is that for those who desire to keep the book as a reference and a guide in their work, a better quality of paper and binding has not been employed.

H. M. BARLOW.

CHEMISTRY

Inorganic Chemistry. By T. MARTIN LOWRY, C.B.E., M.A., D.Sc., F.R.S., 2nd Edn. [Pp. xiv + 1101, illustrated.] (London: Macmillan & Co. Price 25*s*. net.)

IF growth be a sign of health, then the new edition of Prof. Lowry's well-known work—it will be noticed that he refuses to call it by the hackneyed names either of " Textbook " or " Treatise "—bears all the signs of youthful vigour, for it has expanded considerably from the size of the first (1921) edition, familiar to most chemists, and the author has taken the opportunity afforded by the demand for a new edition to revise and recast his work in the light of the new knowledge of the last decade.

In particular the problems of valency have undergone radical changes and full use has been made of Prof. Lowry's own conceptions of " mixed " and " semi-polar " bonds which are discussed fairly early in the book. This dual theory of valency has been brought into the chapter on the properties of salt solutions by introducing the theory of complete ionisation as a logical development of Arrhenius' Theory of Incomplete Ionisation.

The general plan is based as before on the periodic classification with such modifications as have been desirable in the interests of clarity and simplification, and the modern theories of atomic, molecular, and crystalline structures are fully dealt with. The section upon mineral silicates in particular has been rewritten in the light of new knowledge gained by X-ray analysis, and the large number of diagrams and illustrations throughout the book help to make the whole subject eminently clear and readable.

Comparison of the present work with a good book on inorganic chemistry of a generation ago makes it clear that the rather static condition of the subject in pre-war days has now definitely passed and that inorganic chemistry is once more definitely on the move. Prof. Lowry's book will continue to be of great value not only to senior university students, for whom it is mainly intended, but also as a useful revision course on the present state of inorganic chemistry for those who, for one reason or another, may have failed to keep up their reading in this branch of science.

F. A. M.

The Sorption of Gases and Vapours by Solids. By J. W. MCBAIN, F.R.S. [Pp. xii + 577, with 151 diagrams.] (London: George Routledge & Sons, 1932. Price 25*s*. net.)

PROF. MCBAIN is to be congratulated on the production of a very readable and well-arranged summary of the experimental results which have been obtained by the many workers in a field, the present state of flux of which is too pronounced to permit any great degree of critical analysis or definite basis upon fundamental principles. Both the classical theory of adsorption and Langmuir's conception of unimolecular layers have in turn been found insufficient to explain observed facts, even with the acceptance of the existence of various adsorption types, ranging from pure physical condensa-

tion to pure chemical interaction; and the modern trend towards the introduction of energetics into adsorption still further complicates the interpretation of processes involving a time factor.

On the whole, the subject has been very fairly and impartially presented; a short reference to almost every paper of importance is given, usually without comment; and the book thus forms a most valuable index to the literature of the subject, especially since a gratifying number of the original tables, and no less than 151 diagrams, are included. Further, in order to embrace both surface reactions and any accompanying internal effect, the word sorption is widely used in place of adsorption.

The book is divided into three parts, dealing, respectively, with methods of measurement, with experimental data, and with theories of adsorption; and, in the second of these sections, which occupies some three-quarters of the whole volume, separate chapters are devoted to sorption by charcoal, zeolites, silica, glass, metals, and other bodies. Mention may be made of the particularly good index of adsorbing agents, which includes such diversities of bodies as mercury and macaroni, together, in each case, with a list of substances adsorbed.

It is difficult to criticise so excellent a work; but it may be noted, in reading through the volume, that there is an occasional tendency towards dogmatism which is perhaps greater than the present position of the subject warrants. Thus, on p. 313, the interpretation of lack of reversibility in the adsorption of hydrogen by nickel as being due to the slow sinking of the gas into a metallic adsorbent takes no cognisance of the possibility of an energetic explanation. Any faults that the book may possess are, however, minor ones, and detract in no way from the general high standard of the volume, which can be thoroughly recommended, and which will undoubtedly take its place as a standard work of reference.

E. B. M.

Wool Quality: A Study of the Influence of Various Contributory Factors, their Significance and the Technique of their Measurement. By S. G. Barker, Ph.D., Director of Research, Woollen Industries Research Association, with a Preface by the Rt. Hon. J. H. Thomas. [Pp. 328, illustrated.] (London: Pubd. by H.M. Stationery Office for the Empire Marketing Board, Dec. 1931. Price £1 1s. 0d. net.)

"One quality only—the best!" is an advertising slogan frequently seen for the purpose of advocating the virtues of beer, butter, brooms, or bananas; but when we come to the case of wool the matter becomes a great deal more complicated, for the "quality" of wool may itself be qualified in a dozen ways according to its future purpose, and wool is bought and sold on the basis of its "quality," yet this very foundation itself has until recently remained as vague as a Boojum and as intangible as a Snark.

In short, what is wool quality? Is it determined by the cleanness of the raw wool, by the length of the fibres, by their diameter, their tensile strength, straightness, greasiness, colour, or what? Until a decade ago it is fairly safe to say that "wool quality" was like a spiral staircase—something that every wool merchant or spinner could recognise but could not readily describe—and one of the major problems that the Wool Industries Research Association has set out to solve is to settle definitely the basic characteristics that determine the quality of the fibre.

For some years Dr. S. G. Barker, the Director of Research, has urged that more satisfactory scientific standards of quality should be worked out, for as Mr. Thomas remarks in his Preface, "the foundation of such standards would lead to economy in marketing by enabling the manufacturer to specify more exactly the kind of wool he wanted for different purposes."

The present volume is an historical summary of practically all that is known on this complex subject, from the earliest times up to 1931, and affords

a most invaluable work of reference for all who have to deal with wool either in its scientific or technical aspects. It is not possible to do justice to the compilation in a few words, as the ground covered is altogether too extensive—chemistry, physics, mechanics, genetics, and biology are all called upon for help—and the volume illustrates both the necessity for team work when dealing with large problems and the successful way in which this is done at "Torridon," the headquarters of the Research Association.

Last year some £50,000,000 worth of wool was manufactured into goods in this country, so the cost of research cannot run into more than a fraction of a tenth of one per cent. of the value of the wool, not a heavy rate of insurance for the future welfare of the industry; in fact, one wonders if the premium is really high enough!

The chief criticism that can be made against the book is that it is rather impartial and uncritical, so that it can hardly be recommended to students for unaided study, but the summarised information, excellent illustrations, and comprehensive bibliography make it of enduring value to all who have to deal with wool and woollen goods.

F. A. M.

BOTANY

Soil Conditions and Plant Growth. By SIR E. JOHN RUSSELL, D.Sc., F.R.S. Sixth Edition with Illustrations. The Rothamsted Monographs on Agricultural Science. [Pp. viii + 636.] (London: Longmans, Green & Co., 1932. Price 21*s.* net.)

A COMPARISON of the first edition of this invaluable book with succeeding editions is like looking at photographs of an individual at successive periods of his life: the mere stripling of 1912 has, with increasing years, developed both in girth and in weight to such an extent as to be almost beyond recognition; in other words, a monograph of 168 pages has grown into a portly volume of 636 pages. For few books can such a record be claimed in passing through six editions. The reason is not far to seek; in the interval since the book first appeared Soil Science has come into its own, so to speak. During its lifetime there have sprung into existence a number of organisations dealing with the scientific study of the soil such as the International Society of Soil Science, of which the author is the President, the Imperial Bureau of Soil Science, and any number of similar bodies in other countries, as well as a host of workers throughout the world, to say nothing about journals devoted to soil problems. Not the least interesting of these developments is the Russian School of Soil Workers and the gradual spreading of the ideas initiated by them to other parts of the world. Contact with Russian scientists has, in the last few years, been very defective, and we have had to get most of our information concerning them and their work either through American or German sources. In 1930, however, the author attended an International Conference in Russia, and spent some six weeks there, four or five of which were actually spent in the field; the result is that we get now a well-balanced and authoritative account at first hand of the Russian view-point, and this perhaps constitutes one of the outstanding features of this new edition. This is a book which needs no praise; those who are familiar with the author's gift of lucid exposition know well enough what to expect from any of his writings, and will take for granted that this edition has all the good qualities of the previous one with many new ones grafted on. Much of the old matter has been rearranged, while some sections have been so much re-cast as to be almost entirely new. This applies especially to Chapters IV and V, which have been brought into closer relationship to each other by altering the original titles and making them into two subdivisions of the general heading, The Soil in Nature—Chapter IV dealing with the changes in its mineral composition, and Chapter V with changes in the organic matter. It is in the former of these two chapters that the author gives an account of the

contributions of the Russian school to the influence of climate on the composition of the soil and the conception of the soil profile as a significant criterion. This is a book to which all will turn for information on the soil, whether as chemists, botanists, or agriculturists, with conviction that they may there find a well-balanced and broad-minded account of the subject; the book does not suffer from the tendency to stress one or other point of view, which is an unfortunate characteristic of some modern writers, who would interpret all things according to one method only. In the Appendix the methods of soil analysis have been brought up to date, and contain sufficient practical detail to enable any competent person to carry out the experiments successfully.

P. H.

International Address Book of Botanists. [Pp. xvi + 605.] (Published for the Bentham Trustees by Baillière, Tindall, & Cox., 1931. Price 12*s*. 6*d*. net.)

This useful work of reference is the outcome of a resolution passed at the Fifth International Botanical Congress held at Cambridge in 1930. The work was prepared by Prof. Diels of Berlin, Dr. E. D. Merrill of New York, and the late Dr. T. F. Chipp of Kew.

The entries are classified alphabetically under countries, and for each section there is a list of the Botanical Institutions and Societies concerned, directly or indirectly, with the study of plants. There is a collective index to the names, irrespective of nationality, and some idea of the comprehensive character of the work is gained from the fact that this index occupies thirty-seven pages each of four columns of small type and must contain somewhere about twelve thousand names.

The book is well printed on sufficiently thin paper to make the volume easy to handle, but at the same time the paper is opaque enough to make the text easy to read.

Botanists in general owe a considerable debt to all concerned in this production, which is essential to freedom of intercourse between botanists. Furthermore, the chief interests of the various workers is indicated, and this will enable students to get into touch with investigators along similar lines in other parts of the world.

E. J. S.

ZOOLOGY

Fundamentals of Insect Life. By C. L. Metcalf and W. P. Flint. [Pp. xi + 581, with 315 figures and 17 tables.] (London: McGraw-Hill Publishing Co., 1932. Price 30*s*. net.)

In 1928 the McGraw-Hill Publishing Company published *Destructive and Useful Insects*, written by the same two authors. This was rather a massive tome, with a definite bias towards agricultural entomology. The price was high for the average student.

Fundamentals of Insect Life has been written as a textbook of entomology with a biological emphasis. The first ten chapters of *Destructive and Useful Insects* remain, but in a revised and up-to-date form. Chapter VIII, which was entitled "The Orders of Insects," now appears as "The Important Orders and Families of Insects," and has been entirely rewritten and very much enlarged. The chapters (IX and X) on insect control and apparatus for applying insecticides have also had new material added to them. Then, instead of thirteen chapters dealing with insect pests of various crops, domestic animals, and man, there are three new chapters with the following headings: "The Biology and Ecology of Insects: the Living Environment" (Chapter XI); "The Biology and Ecology of Insects: the Physicochemical Environment" (Chapter XII); and "Insect Behaviour" (Chapter XIII). These three chapters will serve as an excellent introduction to the study of insect ecology and behaviour. There are numerous references given as footnotes.

A new feature is the short bibliography of books arranged in the following order: those with emphasis on structure and morphology; on economic importance and control; on ecology; on behaviour and interrelations; on physiology; on the history of entomology, and on beekeeping. There is also a list of bibliographical and abstracting journals, and also a list of American entomological journals and serial publications. Completing the book is a full index.

Many textbooks of entomology have been written, but mostly with a decided tendency to emphasise out of all proportion some one or other of the special branches of the subject, for example, the morphology or the economic side. The present authors have realised this, and are to be congratulated on supplying the student with a well-balanced textbook. While still stressing the importance of a sound basis of morphology, anatomy, physiology, and systematics, adequate attention is given to the biology, ecology, and behaviour of insects as well as to applied entomology. The book should supply a real want. At first sight it is perhaps slightly annoying to find so many familiar illustrations, but as they are good it is not a serious defect. The price is moderate, and should place the book within the reach of a considerable number of students. As to the format of the book, all that it is necessary to say is that it is up to the high standard of a McGraw-Hill book, and that is saying a lot.

H. F. B.

A Naturalist in Brazil: The Flora and Fauna and the People of Brazil. By PROF. KONRAD GUENTHER. Translated by Bernard Miall. [Pp. 400, with 32 plates and 40 text-figures.] (London: George Allen & Unwin, Ltd., 1931. Price 25*s*. net.)

MIALL has performed a useful service in translating into English Guenther's *Das Antlitz Brasiliens*, for it will now reach a circle of readers both in English-speaking countries and in South America who would be unable to use it in its original form. The translation is an excellent one, as might be expected from the well-known skill of the translator; it follows and retains the "flavour" of the original text quite closely, including here and there its somewhat fulsome phraseology.

Prof. Guenther spent a year in Brazil as an adviser to the State of Pernambuco on the control of animal pests, and subsequently he visited also the Argentine. In the present volume, however, the author is not writing as a specialist, but as a general naturalist of wide experience and reading, who has already had his interest in tropical countries aroused by a stay in Ceylon. Nothing in the natural history of the country or its inhabitants is too trivial to receive his appreciative attention, and the result is a most entertaining book that gives a striking survey of the whole subject. It is customary in works of this kind to deal with the journeys undertaken and the observations made during their progress. The author has adopted another and, for the general reader, a more interesting method of presentation in that he has chosen a series of topics, thus bringing together all the observations relating to these various problems. The headings of some of the twenty chapters will illustrate this method: The Scavengers of the Shore, and the Mangrove Woods, Tropical Gardens, Plantations, Nature as an Organism, the Mosaic of Colours, the Symphony of Voices, Epiphytes and Parasites, Pioneers of Communal Life, Wasps and Bees, etc.

Only small matters call for criticism. Certain of the accounts are perhaps a little like some of the trees, rather "tall." For example, it is recorded of the iron-wood tree, Pau de ferro, that its wood is so hard "that the tree can be felled only in the early morning; as the sun grows warmer the iron of the axe becomes softer than the wood, and will no longer cut it." The plates are on the whole good, but some of the text-figures are rather crude and their method of reproduction does not improve them.

It is a book that can be thoroughly recommended to all interested in general natural history and should be in the possession of anyone living in or contemplating a visit to that, to the naturalist, delightful land, Brazil.

C. H. O'D.

The Indian Zoological Memoirs IV. Pila (The Apple-Snail). By Baini Prashad, D.Sc., Superintendent, Zoological Survey of India. [Pp. xi + 83, with 43 figures in the text.] (Methodist Publishing House, Lucknow, 1932. Price Rs. 2.)

The Indian student of zoology has been fortunate in being able to use as his type of a Gastropod Mollusca one of the Apple-Snails of the genus Pila (Ampullaria), some of the largest fresh-water mollusca known. His difficulty has been that he has in his textbooks generally accounts of European forms. This trouble is overcome with the publication of the present useful handbook, which forms the fourth of the series of monographs on Indian animals issued under the general editorship of Prof. K. N. Bahl. Its author, Dr. Baini Prashad, is well known for his work on the Indian Mollusca, which has included a detailed investigation of the anatomy of *Pila globosa*. The material for the present monograph is largely drawn from this previous work, but critically modified and adapted to suit its present purpose.

The account includes brief references to the position, affinities, and nomenclature of the genus as well as a synopsis of its Indian species. Where this can be done, as it is in the present instance, without overweighting the taxonomic side it makes an interesting addition to the more strictly morphological portion which must form the main part of these monographs. The memoir is written in a clear and straightforward manner, so that it is eminently suited for the use of students. The 43 figures are carefully chosen and well reproduced and add materially to the value of the book.

Both the author of the present memoir and the editor are to be congratulated on the addition of a fourth memoir which in utility, manner of presentation, and general get-up is worthy of inclusion in a series whose previous members have set up such a high standard.

C. H. O'D.

A Textbook of Economic Zoology. By Z. P. Metcalf, D.Sc. [Pp. 392, with 236 text-figures.] (London: Henry Kimpton, 1931. Price 18*s*. net.)

This book, according to the author's avowed intention, is an attempt to furnish material for teaching the fundamental principles of zoology from the standpoint of economic zoology. This will appear to many a very bad standpoint from which to present the fundamental principles of zoology. It appears to us to be putting the cart before the horse. We are of opinion that the fundamental principles of zoology should be presented from the standpoint of the pure science and that the superstructure of the economic applications of the subject should be built on this sound foundation.

The method chosen of presenting the principles of zoology leads to many incongruities and to a remarkable lack of proportion and balance in the book. For example, only twelve pages, or one thirty-second part of the whole book, are devoted to the Protozoa and protozoan diseases, whereas eight pages are devoted to the Echinodermata and ten pages to the Cœlenterata. Among the six text-figures in the section on protozoa one is of a sleeping-sickness patient in coma, but there is no figure of a trypanosome. Yet forms such as Pentacrinus among the Echinodermata and Cestus among the Cœlenterata are figured. Surely in a textbook of Economic Zoology Tryanosoma is more important than Cestus or Pentacrinus? Yet there are a number of similar anomalies in the book. Again, surely, Schistosomum is of sufficient importance for its proper scientific name to be given in the legend of its figure, and not

merely to be called "Blood Fluke." Why should Ornithorhynchus be taken as the first type to be described and figured in a section devoted to "A Brief Discussion of Some Common Mammals"?

F. W. R. B.

Handbook of Protozoology. By RICHARD ROKSABRO KUDO, D.Sc. [Pp. x + 454, with 175 illustrations.] (London: Baillière, Tindall & Cox, 1931. Price 25*s*.)

THIS book is intended to provide an introduction to common and representative genera of all the groups of free-living and of parasitic Protozoa. It is intended as a handbook for students taking an advanced course in protozoology as well as a general reference book for teachers and research workers who have not ready access to the various monographs dealing in a more comprehensive manner with the special groups of Protozoa.

The first few chapters are devoted to an excellent general account of the morphology, physiology, and reproduction of Protozoa. The major part of the book provides a systematic account of the taxonomy, biology, and development of the various representative genera. Useful keys to the classification are given and, with the numerous figures, should materially assist in identification. A brief, but useful, bibliography of the more important references is given at the end of each of the thirty-three chapters. Useful hints on collection, cultivation, and observation are given in a brief appendix, and the combined author and subject index is comprehensive. Altogether a very useful book.

F. W. R. B.

An Introduction to Vertebrate Embryology. By H. L. WIEMAN. [Pp, xii + 411, with 201 figures.] (London: McGraw-Hill Publishing Co., 1930. Price 20*s*. net.)

THIS book is intended as an introductory textbook of vertebrate embryology specially suitable for the needs of premedical students. It is designed with the excellent intention of complementing rather than supplementing the laboratory work. The introductory chapters, including sections on general cytology, maturation of the germ-cells, fertilisation and cleavage are followed by a section on the early development of Amphioxus and the frog, considered together. The major part of the book is, however, devoted to the chick embryo and the mammalian embryo. The pig is taken as the type for the latter, and it is assumed that this type will be employed in the laboratory, but a good deal of space is also devoted to human embryology. The illustrations are good and the book contains a useful, if rather limited and scarcely representative, bibliography.

F. W. R. B.

Snakes of the World. By RAYMOND L. DITMARS, Litt.D. [Pp. xii + 208, with frontispiece and 84 plates.] (New York: The Macmillan Company, 1931. Price 30*s*. net.)

THIS book, by the author of *Reptiles of the World*, should prove popular both because of the need for such a book and on account of its excellence. The book is well printed with large type on a quarto-size page and, despite its size, is reasonably light to handle. The style is popular, rather than technical, yet the book contains much interesting and valuable information. The first few chapters are general in character, dealing with the habitat and scope of the snakes, their distribution, habits, and classification. The next four chapters deal with the giant snakes, or pythons, boas, and anacondas; the New-World and the Old-World harmless snakes and the rear-fanged or Opisthoglyph snakes. The remaining five chapters are devoted to the poisonous snakes continent by continent. This geographical method of dealing with the poisonous forms should render the book particularly useful to those about to travel in snake-infested countries who should gain some preliminary

knowledge of the dangerous kinds. But by far the most valuable part of the whole book is the beautiful series of 85 full-page plates. These are photographs finely reproduced by the half-tone process on good paper. There are never more than two photographs on one plate, and in many cases there is only one. The majority are evidently photographs of living specimens, but some are of the skull or whole skeleton to illustrate structural peculiarities. The book is well indexed, but its usefulness would have been greatly enhanced if a bibliography, which, with careful selection need not have been long, had been included.

F. W. R. B.

MISCELLANEOUS

The Geography of London River. By L. RODWELL JONES. [Pp. xii + 184, large quarto.] (London: Methuen & Co., 1931. Price 21*s*. net.)

"LONDON RIVER" is a term familiar to sailors and geographers as the name given to that part of the Thames estuary which lies between London Bridge and the sea. This book is a detailed study of the development and present layout of the great seaport which has grown up on London River, mainly in its relations to the physical setting and to the demands of its commerce.

The three opening chapters describe the physical geography, and the distribution of settlements along the estuary before A.D. 1800. The fourth, and longest, describes the port as it was at the opening of the nineteenth century, when, owing to the increasing size and draught of ships, docks first became necessary to supplement the open quays and wharves which had previously been the only landing-places provided. The account of London Bridge and its effects on the river and port naturally leads up to a survey of the tides and the increase in tidal range which has occurred within the past century. These two chapters give a well-illustrated account of the facts, and will be of very great interest to all students of London.

The latter half of the book is devoted to a description of the modern port and its commerce and equipment. There is a clear analysis of its world-wide traffic, and a comparison with other ports of Great Britain; but there is no attempt at comparison with any foreign port, though such a comparison would be of great interest, particularly in the case of those ports just across the Narrow Seas which are the chief rivals of London in the vast entrepôt trade of western Europe. The table given in *Whitaker's Almanack* for 1932, p. 87, shows that in total tonnage of shipping entered and cleared the first nine ports are, in order, Antwerp, New York, Hamburg, London, Rotterdam, Hong-Kong, Liverpool, Marseilles, and Southampton.

In several of its chapters this volume brings together in an accessible form information which is mostly out of reach of all but specialist students or officials dealing with sections of the port. It is too condensed, and in places too technical in its phrasing, to appeal to the "popular" reader; but those who wish to know more of London, and of the ways and means by which a great port has been developed, than the popular press can tell them will find it well worth the careful reading which it demands.

The volume is well printed and illustrated and well documented; but its index is too brief to be adequate for full reference.

C. B. F.

Stainless Iron and Steel. By J. H. G. MONYPENNY, F.Inst.P. Second Edition. [Pp. 584, with 236 figures and illustrations.] (London: Chapman & Hall, 1931. Price 25*s*. net.)

WHEN the first edition of this book was published in 1926 it was so well received, and deservedly so, that it has remained unchallenged as the standard work on stainless steel, in spite of the fact that progress in the metallurgy of these alloys has been so great during recent years that the book has been badly out-of-date for some time. In the new edition the author has brought

the book really up-to-date. This is not merely a revised edition—it is a new book, double the length of the earlier edition, and containing more than twice the number of illustrations. It will probably remain the standard work on the subject for many years more.

Originally, stainless steel was used only for making rustless cutlery, but now it is hardly too much to say that anything that can be made in ordinary steel can be made in stainless steel. That does not mean that there is one type of stainless steel that will serve all purposes, but that for nearly every purpose a suitable stainless steel can be found among the great number of varieties on the market. In selecting the right type to use for a given purpose, it is necessary to take account of a number of factors, such as the mechanical properties required in the steel, the corroding medium to which the steel will be exposed, the process by which the article is to be fashioned (*e.g.* by hot or cold working, or by welding), and the possibility or otherwise of heat-treating the finished article. If an unsuitable type of steel is chosen, the results are certain to be disappointing, and may even be disastrous.

In this book the author discusses, practically and scientifically, the various types of stainless steel, and explains clearly how the selection of a suitable type for any purpose should be made. The book is so comprehensive that there is no need to give a list of its contents. It contains everything relevant to its purpose, which is to explain to users of stainless steel all that they may reasonably wish to know about it. In all respects the book is excellent.

M. S. Fisher.

Chemical Analysis of Iron and Steel. By G. E. F. Lundell, J. I. Hoffman, and H. A. Bright. [Pp. xiii + 641 pages, with 63 figures.] (New York: John Wiley & Sons; London: Chapman & Hall. Price 42*s*. net.)

This very complete textbook on Iron and Steel Works analysis covers a large field, and provides an enormous amount of chemical and manipulative detail. Both referee and routine methods are described for the analysis of irons, steels, and ferro-alloys, as well as for certain ores, refractories, and other materials.

The subject-matter is divided into five parts. The first of these deals with apparatus, reagents, qualitative tests for steels, sampling, manipulation, and descriptions of special operations. A final chapter gives tables showing the allowable differences and errors, and limits of accuracy for analyses of ferrous materials. Part II deals with the analysis of irons and steels, the first chapter indicating the methods suitable for the different classes of metal. Then follow methods for the determination of: (*a*) the ordinary constituents—Iron, Carbon, Manganese, Phosphorus, Sulphur, and Silicon; (*b*) the common alloying constituents—Copper, Nickel, Chromium, Tungsten, etc.; and (*c*) the less common constituents—Aluminium, Zirconium, Columbium, Tantalum, Boron, Arsenic, etc. Part III gives methods for the determination of Oxygen, Oxide inclusions, Hydrogen, and Nitrogen. The next part deals with the Ferro-alloys, and includes Silicon-Zirconium, Calcium Molybdate, and metallic Manganese, Silicon, Chromium, and Cobalt. Part V describes the analyses of the remaining materials: Ores of iron, manganese, and chromium, Limestone, Fluorspar, Refractories, Slags, Moulding Sands, Coal, and Coke. The book concludes with tables of atomic weights, densities of acid and alkaline solutions, and strengths of sulphuric acid required to give definite humidities.

The general arrangement of the subject-matter within the broad subdivisions already described does not appear to follow any particular system. This is a disadvantage in a book of this nature, which should lend itself to easy and rapid reference. In a few instances the general arrangement is definitely open to criticism. The inclusion of iron amongst the ordinary

constituents of steels is justified on the ground that it may, sometimes, be advisable to determine the iron in order to ensure that no important constituent has been overlooked. It is, however, somewhat surprising to find, under this heading, the colorimetric determination of iron, and the determination of ferrous, ferric, and metallic iron in ores. Again, one would expect to find aluminium and arsenic included amongst the more common constituents of steels.

These, however, are minor defects which are more than balanced by the good features of the book. It is interesting to see that potentiometric methods are given for many determinations, and a diagram showing the pH ranges of hydrogen-ion indicators should prove of value. Another excellent feature is the large number of tables indicating the accuracy to be expected from many of the determinations. The subject-matter is clearly and concisely presented, and the authors are to be congratulated on the care and thoroughness with which they have completed the task of producing a useful and up-to-date reference-work on their subject.

C. W. Dannatt.

Merchant Venturers in Bronze. By Harold Peake and Herbert John Fleure. [Pp. vii + 168, with 67 illustrations.] (Oxford : Clarendon Press, 1931. Price 5s.)

In *Merchant Venturers in Bronze*, the seventh of the series called "The Corridors of Time," the authors have written a short book on a very large subject, and their method has been to convey a great deal in a very few words. The result is that the book is a marvel of compression, and cannot be read without the closest attention.

The opening chapter gives a brief summary of the Craniology of the Bronze Age, with a welcome promise of a larger work to come on this comparatively neglected aspect of archæology. Then, in fifteen pages, we have the main features of the Aunjetitz culture and the somewhat later Early Bronze Age cultures of Germany, France, North Italy, and the Swiss Lake Dwellings. Another fifteen pages give us the cultures of Lausitz, the German Round Barrows, and the Terremare. Eleven pages cover the Middle Bronze Age in Sicily, Matera, and west and south-west France. Eighty-six pages remain for Crete, Greece, Hissarlik, Mesopotamia, Egypt, Iranians, Aryans, and Chinese.

It were idle to complain of dogmatic statements where space has precluded modification, but in some instances clearness has been sacrificed to brevity. We are told, for example (p. 12), that Hissarlik need not be regarded as the place where bronze was first invented, for a clue to this may be found in the fragments of a bowl from the grave of Queen Shubad at Ur. This metal bowl contained 8·5 per cent. of tin, but as the date of the grave is not given the argument is incomplete.

Maps and illustrations are as good and as numerous as could be expected in so small a work, but a reference in the text to individual figures would be very desirable. As it is, the reader is left to find his own way through a group of figures with the aid of very brief captions, and may find himself in difficulties or even quite astray, as with Fig. 18 referring to the Aunjetitz culture : for here the only dagger depicted is a Cypriote one, and, though the instructed reader may know that it was found in Hungary, it is certainly not typical of earliest bronze in Europe. Similarly with regard to Fig. 7, the reader will be misled by finding the Broighter collar among Bronze Age objects.

There is a short bibliography at the end of each chapter, and a list of authorities at the beginning of the book, but some further references in the text would be useful. The reader might not know where best to turn for information about the Bleasedale wood circle or about the few British Megalithic monuments mentioned and the many not mentioned. The Index is of proper names only, and there are some important omissions, including

Hissarlik. Some reference to topics such as agriculture, amber, and the horse would have increased its usefulness.

As in the rest of this series, the get-up of the book is charming, and greatly increases the book-lover's pleasure in handling it.

Tribes of the Niger Delta: Their Religions and Customs. By P. AMAURY TALBOT, M.A., D.Sc. (Oxon), Resident, Nigeria. [Pp. xi + 350, with 86 illustrations and a map.] (London: The Sheldon Press, 1932. Price 18s. net.)

THIS book is a further contribution of the author to the social anthropology of Nigeria. It deals mainly with the Degama Division of the country, comprising an area of nearly 4,000 square miles and having a population of nearly half a million. A systematic account is given of all forms of the beliefs and customs of the people, and the general reader is not likely to find this attractive reading. The treatment is essentially descriptive, and no attempt is made to compare the culture here with any others found outside the area considered. Its northern part is inhabited by some 300,000 Ibo and the remaining people are classed together as Kalabari. The Ibo tribe is said to number over 4,000,000, and it is not clear whether the section of it dealt with here is considered to be typical of the whole or not. No general comparisons are made, even, between the two societies described in detail.

The port of Bonny was probably the greatest slave market in West Africa little more than a hundred years ago. Conditions there have changed greatly since then, and cannibalism and human sacrifice have been abolished as well as slavery. Much of the evidence presented was taken from the proceedings of the native courts. The need for being intimately acquainted with the customs of the people when attempting to administer justice to them is illustrated by numerous examples. Minor deities, or godlings, are known throughout the West Coast of Africa as jujus. "On the whole," the Resident of Nigeria writes, "the respect paid to jujus, other than those with definitely evil rites, is of great help in the administration of the country. Not only does it provide the chief means of guarding against false evidence in court, but it acts as a deterrent from crime, and is more efficacious than our whole anti-criminal machinery."

This volume obviously forms a valuable record of a phase of primitive culture which has already been modified to a great extent by the small white community living in the country, and of which nearly all the original features may be lost in the course of the next few generations. The numerous photographs and sketches are excellently reproduced, and a map of the Niger Delta on the scale of four miles to an inch is provided. The divisions of tribes and clans are shown on this.

β_2.

Human Heredity. By ERWIN BAUR, EUGEN FISCHER, and FRITZ LENZ. Translated by EDEN and CEDAR PAUL. [Pp. 734, with 172 illustrations in the text and 9 plates.] (London: George Allen & Unwin, Ltd., 1931. Price 30s. net.)

THIS book was translated from the third German edition published in 1927, and the authors have supplied supplements and corrections to the English version. There is said to be no other work in any language which covers the same ground, and this is probably true, as it is unusual to find all the topics dealt with here discussed, even in outline, within the covers of a single book. The three parts might, in fact, have been published in three separate volumes with hardly any modification. The first part, by Dr. Erwin Baur, deals with the general theory of variation and heredity, and there are only occasional references to these phenomena in man. Mendelian conceptions are used throughout, as in the parts by the other authors. Dr. Eugen Fischer provides a description of the races of mankind from what is called the "anthropobiological standpoint." This differs from those of the earlier anthropologists,

by taking into account, as far as possible, the hereditary significance of the descriptive characters used. The remaining half of this long book was written by Dr. Fritz Lenz. It deals with the eugenic aspects of the subject, and principally with morbific heredity factors. There are also chapters on the inheritance of psychical characters and on the psychological differences between races of mankind. This volume will be of interest and importance to the geneticist, anthropologist, and eugenist, and hence to all who are concerned with any aspect of human heredity. It appears to give a conscientiously prepared summary of the views on these subjects which are most widely accepted to-day. β_2.

Rediscovering England. By C. A. Simpson. [Pp. xvi + 360, with 44 illustrations and folding geological map.] (London: E. Benn & Co. Price 21*s*.)

This book begins with an introductory chapter in which the influence of the contrasting environments of the towns Oxford, Stroud, and Rugby is investigated to illustrate "geographical control" on their history, and to a certain extent on the present activities. The methods of the explorer are followed, and of those observation, imagination, and map study play the leading part. Published works on districts are mentioned and used, but the main theme is derived from the wayside, the hedgerows, and the bus routes. The value of the O.S. maps as a basis of the study of human geography and history is strongly brought out.

The succeeding four chapters are based upon geological influences in various regions. Those treated are S.E. England, Hampshire and Lower Thames, Midlands and Northern England. Many will regret the omission of such other regions as S.W. England, but the work, according to the author's preface, does not claim to be a complete study of England. The title of the book may be questioned on this account. If such regrets occur, the author's aim has in part been realised—to induce others to fill in the gaps and to amplify her work.

A realisation of incompleteness is a necessary preliminary to completeness.

The remaining section deals with geographical control. It may be that the stress laid upon geology here follows naturally from the previous section, but to many there will be suggested a feeling of over-exaggeration of the geological factor.

This book is of real value to geographers, and will be of great use to all who are engaged on local studies and surveys. May the reviewer be allowed to make a criticism? The constant use of quotations, some of which could easily be replaced by the author's own writings, becomes a little wearisome. Even the best of authorities suffer seriously when given in small snatches. The illustrations are of special value and materially aid the text. A minor fault may be detected in Fig. 23 (p. 137)—surely the position of the treadle should be changed in the view of the Pole Lathe.

J. Eling Colclough.

An Outline of the Universe. By J. G. Crowther. [Pp. xiv + 365.] (London: Kegan Paul, Trench, Trübner & Co., 1931. Price 12*s*. 6*d*. net.)

Mr. Crowther has set out to give us something new, an essay in "the craft of scientific journalism," whose function is to convey the atmosphere and facts of recent scientific research, with the emphasis on the atmosphere, since accuracy of fact is "desirable but less important"—which sounds very like journalism and very unlike science. He has come to the conclusion that present writers on science are chiefly old and worn-out scientists who write for "pocket-money"; whose work is narrow in outlook and too specialised, and so he wants an all-embracing "impersonal scientific journalism."

We agree that the scientific outlook should be spread as far as possible,

and that the future of civilisation depends very largely upon whether this takes place or not, but we are not clear that this will be brought about by a new breed of journalists whose whole-time job it is to select and read books by eminent specialists, and then make a pot-pourri of the matter which they think is important and creative of the scientific atmosphere. Certainly Mr. Crowther's book does not encourage us, in spite of many excellent illustrations and a "jacket by maholy-nagy." It is a pity that he has not the literary ability of the specialists upon whose popular expositions he has drawn, which include Jeans, Eddington, Bragg, Andrade, Haldane, Huxley, and Ogden. The text is interspersed with analogies and digressions which are often trivial and superficial, and the reader's appetite is not whetted by having to swallow nursery words like "powerfuller."

What the atmosphere of science is like when one of its essential constituents, accuracy, becomes of quite secondary importance, may be gathered from such a remark as that on p. 5, which informs the reader that the finiteness of the universe is revealed by "a cursory examination," and from the elementary confusion between mass and weight which occurs in several places, as well as in the definition of energy.

In discussing the origin of civilisation the views of the Diffusionists only are given. This problem of selection is one of the most serious in the production of any "Outline," and it is hard to believe that a scientific journalist is likely to be capable of sufficient discretion in such a difficult matter.

The author has been very ambitious, and consequently his efforts are easy to criticise, but he should be congratulated on having produced a book that not only is interesting, but which looks interesting at first sight—a very necessary prelude to its perusal in the case of large numbers of people, and one which is often neglected by writers of much greater erudition and ability.

G. B. Brown.

France: A Regional and Economic Geography. By Dr. Hilda Ormsby. [Pp. xiv + 515.] (London: Methuen & Co., 1931. Price 21*s*. net.)

Abundant material for a detailed study of France has long been available in numerous regional monographs produced by French geographers; but this is the first comprehensive work of the kind in English. It is therefore very welcome; and Dr. Ormsby's record as a geographer, and her intimate knowledge of France, lead one to expect much.

The book is in three sections, of which the first is mainly devoted to a discussion of the climates and a tentative delimitation of climatic regions. The second section deals with the regional geography and occupies three-quarters of the volume. A separate chapter is devoted to each of the major natural units such as the Paris Basin, the Massif Central, Armorica, and so on. A very brief description of the natural region as a whole prefaces each chapter; but these regional studies are mainly a mosaic of detailed descriptions of the main river basins. The last section is formed by three chapters on Agriculture, Industries, and Communications. These give a valuable summary of the present economic position of France, and correlate much of the detail scattered through the earlier sections into a clear conclusion.

The volume is well illustrated by sketch maps, supplemented by references to the appropriate sheets of the French topographic maps. There are good selected bibliographies as appendixes to the several chapters, and statistical tables are brought together in an Appendix.

One serious defect arises from the adoption of the river valleys as the basis of the regional description. The meticulous description of the courses of the main rivers and their important tributaries, from source to mouth, dominates the regional chapters. This method gives a series of detailed cross-sections which tend to mask the individuality of the several geographical units. Even the major regions, such as the Paris Basin, fail to stand out

distinctly; and the unity of the "pays" is almost, if not quite, hidden. The "Pays de Bray," for example, is described as part of the Oise basin and not as an "enclave" in the chalk plateau; and a later endeavour to make clear its relation to the chalk region is a cause of much needless repetition and cross-reference. In spite of this defect the book is a valuable addition to recent geographical work. It will at once become a standard reference work, and will be particularly welcomed by geographers who know something of France and wish to know more.

G. T.

The Baltic Region. By E. G. Woods, Sc.D. [Pp. 413.] (London: Methuen & Co., 1932. Price 18*s*.)

The "Baltic Region" of this book is what is usually termed the "Baltic Basin," viz. the area between the Scandinavian mountains and the line of the Baltic Heights and the Valdai Hills. Thus it excludes that large part of the area drained to the Baltic Sea which lies to the south of the great End-Moraine; and it is limited to Sweden and Denmark, the republics along the east shore of the Baltic, and the northern coastal districts of Germany and Poland.

The first part of the book is a general consideration of the Baltic Basin, its climate, hydrography, and coastal features. The remainder consists of a treatment of the area in three major "provinces," defined on a geological basis—Baltic Fennoscandia, the Dano-German Province, and the South-east Baltic Province. In each case a summary of the pre-Quaternary geology is followed by a thorough and lucid account of the Quaternary history of the province, and of the rôle played by the events of that period in shaping the present surface features. The chief physiographic regions are outlined; and there are detailed accounts of some smaller districts.

Its sub-title calls the work "A Study in Physical and Human Geography." But it is first and foremost a study of the development of the physical features; and it has little claim to serious consideration as a study in human geography. Indeed, some of the geological material dealt with has little or no geographical significance, and the chapters on the special regions selected for detailed consideration are, apart from their explanations of the land forms, mere topography rather than regional geography.

Nevertheless, the work is a careful study of the evolution of the present surface features of the Baltic Region; and it provides a detailed account of the physical groundplan in which the human life of the region finds its setting. As such it is a work which will be of real value to the student of the geography of the Baltic Region.

A. E. S.

South Georgia: The British Empire's Subantarctic Outpost: A Synopsis of the History of the Island. By L. Harrison Matthews. [Pp. xii + 164.] (Bristol: John Wright & Sons; London: Simpkin Marshall, 1931. Price 15*s*. net.)

The scope of this book is indicated by the headings of its six chapters; viz. Description, Early Voyages, The Sealers, Nineteenth-century Voyages, The Twentieth Century, The Future. The author was a member of the scientific staff of the *Discovery* Expedition of 1924–27. The chief interest, and the larger part, of this book lies in its accounts of the seal- and whale-hunting; there is a clear description of the ruthless wholesale slaughter of these animals before the introduction of restrictions in the early years of the present century. The coast of the island is, as yet, only partly surveyed and the interior is almost unexplored; it is mountainous and mainly occupied by snowfields and glaciers which leave only parts of a narrow coastal strip uncovered during a short summer. The latitude of the island, 54° to 55° S., corresponds to that of northern England from Leeds to the Tyne; but the climate appears to resemble that of the northern shores of Iceland. The

flora and land fauna are very scanty. The island is of economic value only as a base for seal- and whale-" fishing "; and the recent developments of the practice of " whaling " from factory-ships, in lieu of shore stations, may reduce its importance. The book is well printed and illustrated, and is likely to remain for some time the standard work on its subject.

C. B. F.

The Essentials of Bacteriological Technique. By R. F. Hunwicke, B.Sc., A.I.C. [Pp. 108, with 22 figures.] (London: Williams & Norgate, 1931. Price 6*s*. 6*d*. net.)

In 88 pages the author concisely and clearly describes methods of technique which have proved satisfactory in his experience as bacteriologist of the Glaxo laboratory. The text is suitably illustrated with 22 plates and drawings of apparatus, and a subject-index makes for rapid reference.

We fail to appreciate the need for such a book in schools or laboratories. For students of bacteriology it is not comparable in the quantity and quality of its information with Muir and Ritchie (16*s*.), Hewlett (18*s*.), or Stitt (21*s*.); such universally approved textbooks are more likely to be recommended by experienced teachers. Its price would appear to be no justification in view of the popularity among students of the well-known " Aids " series (5*s*.).

The dust-cover announces that the book is part of a " new scientific series," one of which is in preparation for " intelligent laymen." We are sure the intelligent layman will derive satisfaction from Mr. Hunwicke's book.

Tom Hare.

Elements of Chemical Engineering. By W. L. Badger and W. L. McCabe. [Pp. xvii + 625, with 314 figures.] (London: McGraw-Hill Book Co., 1931. Price 25*s*. net.)

In their preface Messrs. Badger and McCabe state: " Thus far, only one important book has appeared to cover this field, namely, *Principles of Chemical Engineering*, by Walker, Lewis, and McAdams . . . originally published in 1923. . . . It is, therefore, with some hesitation that we offer the profession a similar book covering so nearly the same field. Our only excuse for attempting this is that, in spite of the excellence of *Principles of Chemical Engineering*, it is rather difficult for beginning students, or for practising engineers who have not had some training in the underlying theories of the unit operations."

The authors need not have hesitated, for their appointed task has been very well fulfilled.

In general arrangement the book is similar to Walker, Lewis, and McAdams's, much the same sequence of subjects being pursued. It is considerably easier to read, however, owing partly to the lucid descriptions of the principles involved, and partly to the admirable illustrations, which include numerous sections of typical plant. The mathematical side of the subject has been well treated, and the authors have not hesitated to use calculus methods where necessary. There are numerous worked examples and collections of useful problems for solution. There is also a section at the end containing some well-chosen Reference Tables.

It is not only a good textbook for the beginner, but it is also valuable to the more advanced worker, who will find it remarkably comprehensive within the somewhat limited field which the authors have chosen to define their subject. The reviewer says this, feeling that the chemical engineer should be concerned with the design of chemical plant, not merely from the aspect of determining its general form, principal dimensions, and mode of operation, but also with its safety and overall economy, factors which involve a study both of the strength of the materials and methods of plant construction and of the cost factors. These, while occasionally referred to, are apparently regarded by the authors as definitely outside the scope of their book.

Apart from this, the most serious weakness is probably the relative scarcity of references to original papers. A more comprehensive bibliography would have enhanced its value, especially to those interested in chemical engineering research. In spite of these criticisms, this is a sound and inspiring work which can be heartily recommended to all chemical engineers.

W. E. GIBBS.

Johann Kepler: 1571-1630. A Tercentenary Commemoration of his Life and Work. A series of papers prepared under the auspices of the History of Science Society in collaboration with the American Association for the Advancement of Science (Sections A, D, and L). [Pp. xii + 133, with 2 plates and 2 figures in the text.] (Baltimore: The Williams and Wilkins Co., 1931. Agents: Baillière, Tindall, & Cox, London. Price 13*s*. 6*d*. net.)

THE three papers which form the bulk of this book deal with several aspects of Kepler's work and character, and were read by American men of science at a recent celebration of the tercentenary of his death. They are introduced by a Foreword from Sir Arthur Eddington, and are supplemented by a Bibliography.

In the first paper, "Kepler as an Astronomer," Prof. W. Carl Rufus sketches Kepler's chequered career, and traces the chief stages in the laborious process by which he derived his three laws of planetary motion. Kepler's speculations on the physical cause of the planetary motions are also described, and there is an account of his important contributions to optics. There appears to be a slip on p. 21, where the quantity v should be the true anomaly and not the mean anomaly.

The second paper, on "Kepler as a Mathematician," is contributed by Prof. D. J. Struik. It provides a documented summary of the principal results obtained by Kepler in pure mathematics. Some of these results are implicit in the computations of his planetary theory, and are here set out in modern analytical form. Others, relating to volumes of curved solids, maxima and minima, geometry of conics, logarithms, etc., arose out of more deliberate investigations. Their importance for the subsequent development of mathematics is here rightly emphasised. There are a number of slips in the critical Latin passage quoted on p. 41: "Des" should read "Deo" in each case, and "verum" should read "rerum," while there are two obvious misspellings in the last line. Again, the footnote on p. 45 should fall on p. 51; and the date on p. 42 should be 1609.

Some insight into the more speculative flights of Kepler's genius is afforded by Prof. E. H. Johnson's closing essay on "Kepler and Mysticism." This takes the form of a survey of astrology and number-mysticism in Kepler's time, and shows how, while he was influenced by these tendencies, his speculations were saved from futility by his honesty in testing them by continual reference to the results of observation.

The concluding Bibliography has been compiled and annotated expressly for this work by Mr. Frederick E. Brasch, of the Library of Congress. The particulars here collected, of Kepler's writings and correspondence and of the more important secondary literature down to the present day, afford valuable guidance for further study.

The book is well printed and produced. The two plates depict Kepler's portrait and his memorial monument at Weil.

A. A.

Science To-day and To-morrow. Compiled from a Series of Lectures delivered at Morley College. [Pp. 196, illustrated.] (London: Williams & Norgate, 1932. Price 8*s*. 6*d*. net.)

THE collection of essays published in this volume is based on a series of lectures delivered during 1931 at the Morley College for Working Men and

Women. Each essayist discusses the present position and probable trend of his particular science; and each is a leading authority on his subject.

The collection contains some highly varied and very interesting matter, not only for the intelligent general reader of that rapidly growing mass of literature described as "popular science," but also for the scientific reader, who, in these times of increasing specialisation, is often enough little more than a layman when once he steps outside the bounds of his own science. That the book has this valuable characteristic is due to the very evident care which the authors have bestowed on their work and the high standard which they have all set themselves.

Sir Frank Dyson, the Astronomer Royal, writes on "Astronomy," Dr. Emanuel Miller on "Psychology," Prof. F. G. Donnan on "Chemistry and Radiation," Prof. Elliot Smith on "Anthropology," Dr. Jane Walker on "Medicine, its Present Development and Possibilities," Dr. Joseph Needham on "Biology To-day and To-morrow," Prof. H. Levy on "Mechanism—the Foundation of Scientific Rationalisation," Sir Arthur Hill on "Botany," and Prof. W. T. Gordon on "Geology."

The book can be thoroughly recommended to students of science, with interests outside their own subject, as providing a series of excellent summaries of modern scientific thought in its various branches, its applications, and its possibilities.

D. McKie.

The Quest for Power. From Prehistoric Times to the Present Day. By Hugh P. Vowles and Margaret W. Vowles, B.Sc. [Pp. xv + 354, illustrated.] (London: Chapman & Hall, 1931. Price 15*s*. net.)

The authors of this book set out with the object of writing a simple and connected story of man's age-long efforts to augment his bodily powers and to harness the forces of Nature; and they have written what is, essentially, a history of power engineering. It is, moreover, a complete history, since the first chapter opens with an account of early man's flint implements, and the epilogue discusses World Power Conferences.

In the first section the authors show that, before man could make any conscious attempt at supplementing his own feeble bodily powers by harnessing the forces of Nature, he had to serve a long and painful apprenticeship of toil. Here, therefore, they begin with eoliths, the discovery of fire and metals, and primitive bronze founding; and they pass on to irrigation and the large-scale engineering works and structures of ancient Egypt and Babylonia, early methods of transport, rafts, boats, and sailing ships, the first wheels and wheeled vehicles, the beginnings of roads, and that most momentous development in the history of mankind, the introduction of iron implements.

In concluding this first section with an account of early methods of counting, measuring, and time reckoning, and a description of the engineering achievements of Græco-Roman antiquity, the authors write: "Here we must close our survey of man's general acquisition of skill during his age-long apprenticeship based on bodily toil. He still had centuries of heavy bodily exertion ahead of him, he still had to become very much more skilled before he could be called an engineer in the modern sense of the word. But we have now discussed his general advancement up to the point at which he began to experiment with external power. Henceforth . . . his progress in harnessing the forces of nature . . . was to make heavy demands, directly and indirectly, upon the skill and knowledge which he had taken over half a million years to acquire."

The second part of the book deals with the early experiments on steam made by Heron of Alexandria, waterwheels, windmills, the first practical applications of steam and the introduction of coal as a fuel. Then follows a description of the evolution of the steam engine at the hands of Savery, Newcomen, Watt, and their successors. Further chapters describe the

origins and development of the water turbine, the internal combustion engine, the steam turbine, the electric generator, and power-operated tools, and include a survey of modern practice and an account of the production and distribution of power.

The third and last section deals with the past and present methods of obtaining and preparing those fuels and metals that are the materials of power. Naturally, coal, iron, steel, and steel alloys receive most attention, but due space is given to oil, to the possibilities of industrial and power alcohol, and to copper, aluminium, tin, lead, and the non-ferrous alloys. This section ends with an account of the recent World Power Conferences, and a consideration of some possible future developments in power engineering.

As the first attempt at a complete history of power engineering, this book is a notable contribution to the history of science. The authors are to be congratulated on a very fine piece of work, which must have involved enormous labour. They deserve praise, too, for their craftsmanship as writers, and for the large number of valuable illustrations (more than 170) which they have included.

There are a few minor errors: "Murdock" on pp. 169 and 255 should read "Murdoch," and "Bergson" on p. 289 should read "Bergman."

D. McKie.

An Introduction to the Mathematics of Map Projections. By R. K. Melluish, M.A. [Pp. viii + 145, with 30 illustrations.] (Cambridge University Press, 1931. Price 8*s*. 6*d*. net.)

This is by no means a book for beginners, as might be supposed from its title, and is apparently intended for the mathematical rather than for the geographical or general reader. Not only does the author assume familiarity with what the average person would regard as distinctly "higher" mathematics, but the equations and expressions are also developed in a manner not very easily followed, except by mathematical experts.

The book is concerned, in fact, purely with the mathematical side of the matter, and scarcely any illustrative examples are given, or other attempts made to provide those oases in the dry desert of mathematics, which help to cheer and encourage the less sturdy reader.

To say these things, however, is by no means to condemn the book. For the serious mathematical student, no doubt it meets a real need by collecting and stating clearly and concisely (albeit in mathematical language) many results of fundamental importance, not elsewhere collected together, or available in compact form. Quite recent results are included, as well as historical statements.

It is divided into nine chapters, the first introductory; then five chapters devoted to the mathematics of different projections, and three dealing respectively with the deformations of projections, finite measurements, and the best projection for a given country. Chapter VII includes a discussion of the theory of the Indicatrix, and in Chapter IX it is applied to the problem of the choice of a projection.

The value of the book, as a work of reference, could be improved by a much more comprehensive index, by distinctive paragraph headings, especially in earlier chapters, and by numbering the figures.

M. T. M. Ormsby.

Materials and Structures, Vol. I, Elasticity and Strength of Materials. By E. H. Salmon, D.Sc. [Pp. x + 638.] (London: Longmans Green & Co., 1931. Price 15*s*.)

Dr. Salmon's book forms a notable addition to engineering literature. It is comprehensive and thorough, covering the usual ground, and containing in

addition chapters on the mathematical theory of elasticity and on metallography. Numerous examples are provided for the ordinary student, while the references at the ends of the chapters will enable the advanced student to see the subject as a living one, and will guide him to its extensive and growing literature.

A little more than half of the book is given to the ordinary range of theory. Among new features in this part may be mentioned an account of the membrane analogy by which Prandtl dealt with the torsion of cylinders, and its development into the use of soap films by Griffith and Taylor. The chapter on columns is, as might have been predicted from a knowledge of the author's book on this subject, unusually full and good.

The second half of the book begins with two chapters on the general theory of elasticity, developing this until the theories of torsion and of the bending of plates can be given. These chapters are devised as an introduction to Prof. Love's standard treatise, and are, in consequence, rather more difficult for an engineer to read than would be the case if they had been written with his special requirements in view. But the author has taken the view that, as it is impossible in a book of this size to give more than a brief introduction to the theory, it is better to lead the reader towards a standard treatise than to give him an easier introduction that does lead beyond itself.

With the exception of the last chapter the rest of the book deals in a very thorough manner with the properties of materials and with testing methods. The question of the fatigue of materials is given its due prominence, and tests of metals at high and low temperatures are described. The last chapter is an introduction to metallography. It is, of course, impossible to do justice to the subject in so short a space, but the author has given an excellent summary, and his extensive references will enable the interested reader to continue his studies in any direction that he finds attractive.

R. C. J. H.

Economic Control of Quality of Manufactured Product. By W. A. Shewhart, Ph.D., Member of the Technical Staff, Bell Telephone Laboratories, Inc. [Pp. xiv + 501.] (London: Macmillan & Co., Ltd., 1931. Price 30*s*.)

"A large amount of work has been done in developing statistical methods on the scientific side, and it is natural for anyone interested in science to hope that all this work may be utilised in commerce and industry. There are signs that such a movement has started, and it would be unfortunate indeed if those responsible in practical affairs fail to take advantage of the improved statistical machinery now available."

These words appeared in *Nature* in January 1926, and now, after six years, there is clear evidence to show that the movement referred to has developed steadily if slowly. The use of statistical method in such problems as the forecasting of economic conditions, the prediction of prices and changes in demand has been realised for some time, but what is of newer growth is the recognition that modern industry with its aim at making the same thing again and again, provides problems which are inherently statistical in nature. In the United States the importance of these problems has been sufficiently realised for the American Society for Testing Materials, the Society of Mechanical Engineers, the Mathematical Society, and the Statistical Association, to appoint a joint committee to study the development of statistical applications in the engineering and manufacturing fields. In its practical reinforcement the movement has been primarily associated with the companies forming the Bell Telephone System, and Dr. W. A. Shewhart, the writer of the book under review, may perhaps be described as the chief link in the States between the theoretical statistician and the practical industrialist.

After the number of books on statistical method which have recently been

turned out containing an uncritical application of formulæ to the data of experience, it is a real pleasure to find a book based upon a well-thought-out and logical philosophy. No mathematical model can exactly fit the facts as we meet them without the introduction of assumptions and approximations; it follows that a study of the conditions upon which probability theory may be used for the purposes of practical inference is one of the most important problems in the application of statistics. This problem Dr. Shewhart has tackled, recognising that in the industrial field, as in perhaps few others, the soundness of new methods will be judged critically by the value of the results.

Briefly one may perhaps summarise the author's approach to the subject as follows: We know that the characters of individual things or events vary; granted that there is variation, we can express in mathematical terms how this will occur under what may be termed a constant system of chance causes: in experience we find that certain things do vary in this way; others do not. Modern statistical theory is introduced to distinguish between these cases, to point out to the investigator when the production of an article is "under control," and when there are "assignable causes" of variation, that it is worth while seeking to eliminate. The value of the book lies not so much in its exposition of statistical theory—indeed, certain of the most recently developed methods of analysis are not discussed—but in its extreme suggestiveness to those interested in the application of scientific method to industry.

Many practical illustrations are given throughout the text, largely, but not wholly, taken from the engineering field. How is a manufacturer to judge whether the fluctuations in the fraction of defective parts turned out per week is excessive? How large a sample of a certain product should be inspected to determine with reasonable assurance the quality of a "lot" of given size? How may the tensile strength of steel best be judged from a correlated measure of hardness? What principles should govern the fixing of specifications of quality, having regard both to the needs of the consumer, and to the inevitable limitations of the manufacturing process? Such questions as these can only be answered to best advantage with the help of statistical methods.

The volume ends with a bibliography containing references for further study in connection with each of the seven parts into which it is divided.

E. S. P.

Practical Microscopy. By L. C. Martin, D.Sc., and B. K. Johnson, F.R.M.S. [Pp. 116, with 88 figures.] (London and Glasgow: Blackie & Son, 1931. Price 3*s*. 6*d*. net.)

In this small volume, the authors have confined themselves to a simple and concise account of the optical principles and physical limitations involved in practical microscopy. It is evident that they have assumed that the reader has some knowledge of geometric and physical optics, and has had experience in the practice of microscopy.

The book commences with a chapter on magnification and the methods of its determination, including focometry and micrometry. This is followed by a description of the stand and mechanical parts of a typically modern microscope together with a brief account of optical elements. Although brief, the chapter on numerical aperture and resolving power brings out clearly the physical limitations of the microscope.

In dealing with the methods of illumination the authors have laid down definite rules for adjusting the optical parts. If these are carried out in the order given, workers should find no difficulty in quickly obtaining good results so far as the transmitted-light image is concerned. It is doubtful, however, whether the method given by the authors for dark-ground illumination would prove so successful, especially when high-angle illuminators are used in con-

junction with objectives of high numerical aperture, since with these the resulting image is extremely sensitive to slight errors of centration of any of the optical parts.

A short account of the apparatus used in ultra-violet microscopy is given, together with a chapter on the interpretation of the image.

The book is well illustrated throughout.

J. E. B.

The Sexual Life of Savages in North-western Melanesia. By BRONISLAW MALINOWSKI, with preface by HAVELOCK ELLIS. Third Edition. [Pp. 506, with 96 plates.] (London: George Routledge & Sons, 1932. Price 15*s*. net.)

THE first edition of this outstanding work of Prof. Malinowski appeared in 1929 and has been translated into French, German, and Spanish. It was at once recognised as an important contribution to ethnological literature, for it gave the first ethnographic account of sexual life amongst a primitive people which has any claim to completeness. In a foreword to the new edition the author expresses himself as disappointed with the reception accorded to the earlier editions in the light of a scientific achievement, and with lack of appreciation of its main aim, which was "to show that from whichever side you approach it, the problem of sex, family, and kinship presents an organic unity which cannot be disrupted." Whether by yielding to the natural demand for a reissue of the work at a popular price, Prof. Malinowski will accomplish his object any better is problematical, for it is to be feared that the selection of sensational details which appeal to the popular as distinct from the scientific taste, of which he complains, will be no less evident when the book is to be found on the shelves of every library.

The book gives an account of everything pertaining to sex which could be ascertained by an ethnographer having rare qualities of scientific knowledge, patience in observation, enthusiasm for truth and sympathetic insight, during a long residence among the Trobriand Islanders, and as such it has an assured place in scientific literature whatever its format. When such a subject is presented with literary charm and a wealth of picturesque description in the form of an attractively produced popular edition it is inevitable that the book will be sought after by very many who are not actuated by the same motives as the author. There is also the danger that, taking advantage of the licence allowed under the guise of science, this example may be followed by a spate of similar works written by people neither so well qualified to write nor so highly motived as Prof. Malinowski. If these are confined to the recital of facts it may be possible to endure them, but if in the name of science we are to be treated in the future also to verbatim and detailed accounts of all the imaginative myths, legends, and stories relating to sex life which may be recited to investigators in this field, our literature will not be enriched.

Even in this work some material has been included which is out of place in a popular book. This includes some imaginative stories which, being no better nor worse than those which could be overheard elsewhere than in Melanesia, and being without foundation in fact, as far as the author could ascertain, make no obvious contribution to science and could have been omitted. For other reasons the discussion of sexual perversions is inadvisable in a popular work. If it is deemed necessary to make a record of sex matters which border on the pathological, the proper place for such a record is a scientific journal. The medical investigator does not publish in popular form details of his experience which it may not be in the public interest for all and sundry to read, and it would be well if scientific workers in such fields as this would exercise the same restraint when popular editions are being issued. The omission of a few pages would have made such a protest unnecessary in relation to the present work.

The subject matter in the book which has aroused most interest is the Tobrianders' ignorance of paternity, and the influence of this curious phenomenon upon the whole of their family system. It seems to the reviewer that Prof. Malinowski has not sufficiently emphasised the importance of a mysterious factor without which this ignorance of the share of the male in procreation could hardly have persisted. We are given to understand that marriage is not entered upon at a much earlier age than in our own civilisation, that sexual intercourse is as regularly practised from adolescence until marriage as in the married state, that no contraceptive measures are employed, and that, nevertheless, premarital pregnancy is rare. To quote from p. 166, "it is very remarkable to note that illegitimate children are rare. The girls seem to remain sterile throughout their period of licence, which begins when they are small children and continues until they marry; when they are married they conceive and breed, sometimes quite prolifically. . . . To have prenuptial children is . . . considered reprehensible." The author admits that this constitutes an unsolved problem, and he goes on to say that "it is amusing to find that the average white resident or visitor to the Trobriands is deeply interested in this subject only, of all the ethnological problems opened to him for consideration." He does not suggest, however, that it is of fundamental importance to these other ethnological problems.

From the fertility inquiry carried out in England at the census of 1911 it was found that girls married at the age of seventeen would have on the average three children each before the age of twenty-four, the mean age at marriage in the population being about twenty-five years. The mean age at marriage of the Tobrianders is not estimated, but even supposing it to be five years younger than in England, an average of about two prenuptial children per girl would be expected if unrestricted intercourse were practised from adolescence onwards in the manner described. In the ordinary course of nature as it is known to us this is what would happen, and not only would the family system of the islanders be impossible, but they could scarcely have fallen into the error of overlooking the causative association between sexual intercourse and pregnancy and consequently founding a matrilineal system of succession, social obligations, and taboos upon it. For this reason it is puzzling why Prof. Malinowski treats this merely as an interesting detail and does not see in this unexplained mystery a fundamental missing link in his chain of origins.

In its many other features the work is a model of painstaking and thorough ethnographic fieldwork, and of synthetic description of the results of such work. The new edition is well produced and effectively illustrated.

P. S.

The Psychology of a Primitive People. A Study of the Australian Aborigine. By STANLEY D. PORTEOUS, Professor of Clinical Psychology in the University of Hawaii. [Pp. xv + 438, with 48 illustrations.] (London: Edwin Arnold & Co., 1931. Price 30*s*. net.)

NORMAL psychology means for us the psychology of normal white people living in a highly civilised state. The question whether the generalisations derived from a study of the comparatively small section of the population of the world to which we belong are also true for less civilised peoples is one which has often been discussed without leading to any very positive conclusions. Are there innate racial differences in psychological traits, or can the differences in behaviour observed be attributed to differences in opportunity and environment? Anthropologists have had much to say on this subject, but this book offers an approach from an angle different from theirs, as it describes an examination of primitive groups made by using the quantitative method of modern experimental psychology. A few investigations of this kind have been carried out in other parts of the world, but this study claims to be a pioneer one as far as the natives of Australia are concerned. These peoples

form ideal material in some ways, since they are supposed to constitute a homogeneous race which was segregated for a long time before the arrival of Europeans and which is spread over the enormous area of a continent in which a great diversity of physical conditions is found.

Prof. Porteous says that from the inception of the work he determined to interpret his task in as broad a psychological sense as possible. Besides the actual testing he decided to make a survey of the conditions of life in different districts and of the customs of the people which might be taken to indicate mental differences. The first part of his long book, which forms just half of the whole, is entitled "Aboriginal Environment," and it aims at giving a complete picture of the conditions of native life in the localities visited. This is written in the form of a narrative of the expedition, and it is a lucid and entertaining account which should be appreciated by the general reader. The districts visited were the extreme north-west of the continent—the coastal regions of Dampier Land and the inland district of East Kimberley—and Central Australia. The comparatively favourable conditions found in the former region are contrasted with the dangers of the central deserts, where drought and scarcity of food are perpetually feared. Even in this descriptive part the writer adopts the attitude of an apologist for the natives, and he questions how their social life could have been better organised to promote survival in times of stress. Occasional tests were applied to the natives apart from the scheduled list. For example, it has frequently been asserted that they are able to recognise the footprints of any individual with whom they happen to be acquainted. An actual trial showed, however, that the most skilful did not have more than fifty per cent. of successes, and no native could distinguish with certainty the footprints of his fellows from those of white men. Their skill in tracking animals cannot be doubted, and it has often been suggested on this account that their senses are more acute than those of civilised people. No tests of sensory acuity seem to have been taken by the members of this expedition.

The second part of this book is entitled "Aboriginal Intelligence," and the first six chapters of it deal with such general questions as the handicaps of environment, beliefs and customs, and the mental attributes which can be estimated from data of this kind. The question of the origin and dispersion of the natives over the continent is considered incidentally and it is concluded that the landing was in Western Australia and that the dispersal over the continent did not take place until after the habits of the race had become fixed and established. In dealing with matters of social anthropology the author had to rely primarily on the records of earlier investigators, since his own stay in the country only lasted for five months. He contends that nearly all the customs of the natives had their origin in expediency and that, though many have been greatly modified, they still serve to consolidate the social groups. The general conclusion seems to be that the culture is remarkably uniform for all these groups and that the slight modifications which are found were adaptations to local environmental conditions. Of the two groups which he examined Prof. Porteous says that they "have in the main the same tribal organisation, the same ideas and social customs, the same fundamental beliefs, the same modes of life, the same dependence on the same animals and plants for subsistence. Yet though the materials of existence are identical, the struggle to obtain them is entirely different in degree. . . . What effect would this modification of physical environment have on racial character and intelligence?" This question cannot be answered then from a comparative study of customs, habits, and social institutions, and if any solution is to be reached it must depend on estimates of "racial character and intelligence" of another kind.

In the first three-quarters of this book there is little new material presented and no new methods are used. Some of the conclusions reached are rather

novel and there is no doubt that these might be contested. It is claimed that the concluding chapters break new ground in so far as the native population of Australia is concerned, since they give the results of a direct examination of physical and mental capacities. The difficulties of the inquiry are first explained. The tests had to be limited to ones which could be made independent of verbal instructions, and they also had to be as easy and as familiar to the subjects as possible. The schedule adopted actually took about ninety minutes to apply. The mental tests were designed, as far as possible, to test innate as distinct from acquired abilities. After reading the lengthy introduction to this inquiry the reader may well be disappointed when he finds that the total numbers of natives tested are 130 men, 11 women, and 127 children. For various reasons the full schedule was not applied to all these subjects, and it must be remembered that they had to be divided into groups in order to make comparisons between the populations in the two areas visited. It may be safely asserted that on the basis of such meagre material no answers of any permanent value could be given to the important questions enunciated. The sample might have to be increased tenfold before any reliable conclusions could be reached. The small sizes of the samples examined might have been compensated for to some extent by taking a large number of measurements. Records of five anthropometric characters are considered first, *viz.* sitting and standing height and the length, breadth, and height of the head. The differences of the male adult means for the north-west and central groups are just significant in the case of the head length and breadth, but it would be unsafe to assume that there are distinct racial varieties in the two districts without further evidence. The so-called psycho-physical measurements relate to five muscular tests and vital capacity, and no significant differences whatever are found for these. The only other tests applied to the adult subjects are eight designed to measure temperament and intelligence. They are a maze test, a test requiring the assemblage of drawings of different parts of common objects, another dealing with wooden geometrical figures which have to be placed in spaces made to receive them, a digits memory test, two simple visual memory tests, one testing ability to recognise footprints and another requiring the arrangement of a set of cards in the order of the number of dots marked on each. Only one significant difference is found between the average performances of the natives of the north-west and central areas respectively. For all the tests applied no markedly significant differences were found between these two groups, and, as far as this investigation can show, it would be unsafe to assert that they are differentiated in any way. At the same time the inquiry was not extended enough to show that there are no differences of any consequence between the characters of the two groups examined. Comparisons with the records available for other races suggest that the Australian natives are as inferior as any other primitive peoples and the average mental age of the adults is about the same as that of normal white children eleven years old. Difficulties of technique and the uncertainty as to whether the natives were really exerting themselves to the utmost in performing tasks to which they are unaccustomed make such results difficult to interpret, however. Prof. Porteous ends the description of his experimental work rather abruptly, and we are not offered any solutions to the main problems which he had set out to examine by these means. His general conclusion is "that the Australians as a race are unadaptable to our kind of civilisation, although excellently adjusted, both socially and psychologically, to their own natural environment." This is a pioneer study, and if work in this direction is to prove of permanent value the number of individuals examined must be greatly increased. There is an obvious need, too, for an extension of the number of tests taken, and many of sensory and other physiological characters might be added with advantage.

B.

BOOKS RECEIVED

(*Publishers are requested to notify prices*)

The Queen of the Sciences. By E. T. Bell, Professor of Mathematics in the Californian Institute of Technology. London: Baillière, Tindall & Cox; Baltimore: The Williams & Wilkins Company, 1931. (Pp. 138, with 9 figures.) Price 5*s*. 6*d*. net.

The White Dwarf Stars. Being the Halley Lecture delivered on May 19, 1932, by E. A. Milne, M.A., Rouse Ball Professor of Mathematics in the University of Oxford. Oxford: at the Clarendon Press, 1932. (Pp. 32.) Price 2*s*. 6*d*. net.

Advanced Algebra. Vol. I. By Clement V. Durell, M.A., Senior Mathematical Master, Winchester College. London: G. Bell & Sons, 1932. (Pp. viii + 193.) Price 4*s*. net.

Foundations of Point Set Theory. By R. L. Moore, Professor of Pure Mathematics, University of Texas. New York: American Mathematical Society, 501 West 116th Street, 1932. (Pp. vii + 486.)

Differential Equations from the Algebraic Standpoint. By Joseph Fels Ritt, Professor of Mathematics, Columbia University. Colloquium Publications, Vol. XIV. New York: American Mathematical Society, 501 West 116th Street, 1932. (Pp. x + 172.) Price $2.50.

The Mysterious Comet, or the Origin, Building Up, and Destruction of Worlds by means of Cometary Contacts. By Comyns Beaumont. London: Rider & Co., Paternoster House, E.C. (Pp. 288, with 19 plates.) Price 10*s*. 6*d*. net.

Electrons and Waves. An Introduction to Atomic Physics. By H. Stanley Allen, F.R.S., Professor of Natural Philosophy and Director of the Physics Research Laboratory in the United College of the University of St. Andrews. London: Macmillan & Co., St. Martin's Street, 1932. (Pp. 336.) Price 7*s*. 6*d*. net.

Elementary Mechanics. By A. Buckley, M.A., Senior Mathematical Master, Wellington College, and C. F. G. Macdermott, M.A., Assistant Master, Wellington College. London: G. Bell & Sons, 1932. (Pp. viii + 216.) Price 4*s*. net.

Intermediate Physics. By C. J. Smith, Ph.D., M.Sc., A.R.C.S., Lecturer in Physics, Royal Holloway College, University of London. London: Edward Arnold & Co., 1932. (Pp. viii + 650.) Price 14*s*. net.

Müller-Pouillets Lehrbuch der Physik. II Auflage. Vierter Band. Erster Teil. Grundlagen der Lehre von der Elektrizität und dem Magnetismus. Unter Mitwerkung von O. V. Auwers, Berlin-Siemenstadt, und H. Hermann-Berlin, bearbeitet von Siegfried Valenturier Braunschweig: Friedr. Vieweg & Sohn Akt.-Ges., 1932. (Pp. xxi + 752, with 744 figures.) Price 47.50 RM.; bound, 51 R.M.

Recent Advances in Atomic Physics. By Gaetano Castelfranchi, Professor in the High School for Engineers in Milan. Approved Translation by W. S. Stiles, Ph.D., Scientific Assistant, the National Physical Laboratory, Teddington, and J. W. T. Walsh, M.A., D.Sc., Principal Assistant, the National Physical Laboratory, Teddington. In two volumes. London: J. & A. Churchill, 40 Gloucester Place, Portman Square, 1932. (Pp., Vol. I, xii + 360, with 111 figures; Vol. II, xii + 400, with 79 figures.) Price 15*s*. each volume.

Modern Methods in Quantitative Chemical Analysis. By A. D. Mitchell, D.Sc. (Lond.), F.I.C., Scientific Assistant, University of London, and A. M. Ward, Ph.D., D.Sc. (Lond.), A.I.C., Lecturer in Inorganic Chemistry, Sir John Cass Technical Institute. London: Longmans, Green & Co., 1932. (Pp. xi + 178.) Price 6*s*. net.

Introduction to Organic Chemistry. By Roger J. Williams, Professor of Chemistry, University of Oregon. Second Edition. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1932. (Pp. xi + 585.) Price 21*s*. net.

Industrial Chemistry. A Manual for the Student and Manufacturer. Edited by Allen Rogers, Head of Department of Chemical Engineering, Pratt Institute, Brooklyn, N.Y. In Collaboration with others. Fifth Edition. London: Macmillan & Co., St. Martin's Street, 1931. (Pp., Vol. I, xiv + 641, with 266 figures; Vol. II, xii + 642–1517, figures 267–441.) Price 30*s*. each volume.

Modern Chemistry. The Romance of Modern Chemical Discoveries. By Frederick Prescott, M.Sc., Ph.D., A.I.C., Lecturer in Chemistry in the Chemistry Department. The Polytechnic, Regent Street, W.1. London: Sampson Low, Marston & Co. (Pp. xiii + 370, with 42 diagrams and 39 plates.) Price 12*s*. 6*d*. net.

Organic Syntheses. Collective Vol. I. Being a Revised Edition of Annual Vols. I–IX. Editorial Board. Henry Gilman, Editor-in-Chief. New York: John Wiley & Sons; London: Chapman & Hall, 1932. (Pp. ix + 564.) Price 37*s*. 6*d*. net.

The Chemistry of the Monosaccharides and of the Polysaccharides. By Hans Pringsheim, University of Berlin. London: McGraw-Hill Publishing Co., Aldwych House, W.C.2, 1932. (Pp. vi + 413.) Price 24*s*. net.

Chemical Encyclopædia. A Digest of Chemistry and its Industrial Applications. By C. T. Kingzett, F.I.C., F.C.S. Fifth Edition. London: Baillière, Tindall & Cox, 7 Henrietta Street, Covent Garden, W.C.2, 1932. (Pp. vi + 1014.) Price 40*s*. net.

Microchemical Laboratory Manual. By Friedrich Emich, Professor at the Technische Hochschule of Graz. With a Section on Spot Analysis, by Dr. Fritz Feigl, Privatdozent at the University of Vienna. Translated by Frank Schneider, Sc.M. New York: John Wiley & Sons; London: Chapman & Hall, 1932. (Pp. xvi + 180, with 88 figures.) Price 18*s*. 6*d*. net.

Organic Synthesis. An Annual Publication of Satisfactory Methods for the Preparation of Organic Chemicals. Frank C. Whitmore, Editor-in-Chief of Editorial Board. Vol. XII. New York: John Wiley & Sons; London: Chapman & Hall, 1932. (Pp. vii + 96.) Price 10*s*. 6*d*. net.

An Introduction to the Scientific Study of the Soil. By Norman M. Comber, D.Sc., A.R.C.S., F.I.C., Professor of Agricultural Chemistry in the University of Leeds. Second Edition. London: Edward Arnold & Co., 1932. (Pp. 208.) Price 7*s*. 6*d*. net.

A Course of Practical Work in Agricultural Chemistry for Senior Students. By T. B. Wood. New Edition. Revised by H. H. Nicholson. Cambridge: at the University Press, 1932. (Pp. 56.) Price 2*s*. 6*d*. net.

Explosives: Their History, Manufacture, Properties, and Tests. By Arthur Marshall, A.C.G.I., F.I.C., F.C.S., formerly Chemical Inspector, Indian Ordnance Department. Second Edition. Vol. III. London: J. & A. Churchill, 40 Gloucester Place, Portman Square, 1932. (Pp. xiii + 286, with 14 illustrations.) Price 42*s*. net.

The Heat Treatment and Annealing of Aluminium and its Alloys. By N. F. Budgen, Ph.D., M.Sc., Superintendent Wm. Mills' Aluminium Foundries. With a Foreword by D. Hanson, D.Sc. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1932. (Pp. xvii + 341, with 231 figures.) Price 25*s*. net.

Protective Films on Metals. By Ernest S. Hedges, M.Sc., Ph.D., D.Sc. Being Volume Five of a Series of Monographs on Applied Chemistry, under the Editorship of E. Howard Tripp, Ph.D. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1932. (Pp. xi + 276.) Price 15*s*. net.

Liesegand Rings and other Periodic Structures. By Ernest S. Hedges, D.Sc., M.Sc., Ph.D., A.I.C. London: Chapman & Hall, 11 Henrietta Street, W.C.2, 1932. (Pp. viii + 122.) Price 10*s*. 6*d*. net.

Soils: Their Origin, Constitution, and Classification. An Introduction to Pedology. By Gilbert Wooding Robinson, M.A., Professor of Agricultural Chemistry in the University College of North Wales, Bangor. London: Thomas Murby & Co., 1 Fleet Lane, E.C.4; New York: D. van Nostrand Co., 250 Fourth Avenue, 1932. (Pp. xv + 390, with 12 illustrations.) Price 20*s*. net.

Explanatory Notes to accompany a New Geological Map of the Commonwealth of Australia. Based on the maps already published by the Geological Surveys of the Various States, etc. By Sir T. W. Edgeworth David, K.B.E., C.M.G., D.S.O., M.A., etc., Professor Emeritus of Geology, University of Sydney. London: Edward Arnold & Co.; Sydney: Australian Medical Publishing Company, The Printing House, Seamer Street, Glebe, 1932. (Pp. 175, with 10 figures.) Price, with map in four parts, each 42 × 34 inches, unmounted, 20*s*. net; or with map in four parts, in twenty-eight sections mounted on linen, contained in a case, 42*s*. net.

An Introduction to Geology. Third Edition. Rewritten throughout. By William Berryman Scott, Ph.D., Hon.Sc.D., LL.D., Blair Professor of Geology, Emeritus in Princeton University. New York: The Macmillan Company, 1932. (Pp., Vol. I, xiii + 504, with 264 figures; Vol. II, vii + 485, with 389 figures.) Price 16*s*. and 14*s*. respectively.

A Textbook of Geology. Part I. Physical Geology. By Chester R. Longwell, Adolph Knopf, and Richard F. Flint. New York: John Wiley & Sons; London: Chapman & Hall, 1932. (Pp. xii + 514, with 341 figures.) Price 23*s*. net.

A Textbook of Mineralogy, with an Extended Treatise on Crystallography and Physical Mineralogy. By Edward Salisbury Dana, Professor Emeritus of Physics, Yale University. Fourth Edition, Revised and Enlarged, by William E. Ford, Professor of Mineralogy and Curator of the Mineral Collections, Sheffield Scientific School of Yale University. New York: John Wiley & Sons; London: Chapman & Hall, 1932. (Pp. xi + 851.) Price 34*s*. net.

Chromosomes and Plant-breeding. By C. D. Darlington, Ph.D., D.Sc., Cytologist, John Innes Horticultural Institution. With a Foreword by Sir Daniel Hall, K.C.B., F.R.S., Director of the John Innes Horticultural Institution. London: Macmillan & Co., St. Martin's Street, 1932. (Pp. xiv + 112, with 25 figures.) Price 7*s*. 6*d*. net.

An Illustrated Synopsis of the Principal Larval Forms of the Order of Coleoptera. By Adam G. Böving, Ph.D., Senior Entomologist, U.S. Bureau of Entomology, Washington, D.C., and F. C. Craighead, Ph.D., Principal Entomologist, U.S. Bureau of Entomology, Washington, D.C. Reprinted from *Entomologica Americana*, a Journal of Entomology. Vol. XI. (Pp. 351, with 125 plates.) Price, Paper Cover, $6.50; Cloth Bound, $7.50.

The Causes of Evolution. By J. B. S. Haldane, F.R.S. London: Longmans, Green & Co., 1932. (Pp. vii + 234.) Price 7*s*. 6*d*. net.

Hearing in Man and Animals. By R. T. Beatty, M.A., B.E., D.Sc., Senior Scientific Officer, Department of Scientific Research and Experiment, Admiralty. London: G. Bell & Sons, 1932. (Pp. xi + 227.) Price 12*s*. net.

Biology for Medical Students. By C. C. Hentschel, M.Sc. (Lond.), Lecturer in Zoology, Chelsea Polytechnic, and W. R. Ivimey Cook, B.Sc., Ph.D. (Lond.), Lecturer in Botany, the University, Bristol; with a Foreword by G. E. Gask, C.M.G., D.S.O., F.R.C.S. London: Longmans, Green & Co., 1932. (Pp. xii + 618, with 413 figures.) Price 18*s*. net.

A Textbook of Practical Entomology. By Frank Balfour-Browne, M.A., F.R.S.E., F.Z.S., F.L.S., F.E.S. London: Edward Arnold & Co., 1932. (Pp. viii + 191, with 116 figures.) Price 18*s*. net.

Fundamentals of Biology. By J. W. Stork, M.A., Biology Master, Charterhouse, Godalming, and L. P. W. Renouf, B.A., Dip. Agric., Professor of Zoology, University College, Cork. London: John Murray, Albemarle Street, W. (Pp. xv + 448, with 180 figures.) Price 6*s*. net.

Evolution of Sex and Intersexual Conditions. By Dr. Gregorio Marañon, Professor at the University of Madrid. Translated from the Spanish by Warre B. Wells, with new Appendix. London: George Allen & Unwin, Museum Street. (Pp. 344.) Price 15*s*. net.

Recent Advances in Cytology. By C. D. Darlington, D.Sc., Ph.D., Cytologist, John Innes Horticultural Institution. With a Foreword by J. B. S. Haldane, M.A., F.R.S., Head of Genetical Department, John Innes Horticultural Institution. London: J. & A. Churchill, 40 Gloucester Place, Portman Square, 1932. (Pp. xviii + 559, with 109 text-figures and 8 plates.) Price 18*s*. net.

Biology. An Introduction to the Study of Life. By H. Munro Fox, Professor in the University of Birmingham. Cambridge: at the University Press, 1932. (Pp. xiv + 344, with 152 figures.) Price 6*s*. net.

Bees, Wasps, Ants, and Allied Insects of the British Isles. By Edward Step, F.L.S. London and New York: Frederick Warne & Co. (Pp. xxv + 238, with 44 plates in colour showing 470 figures, 67 plates showing 170 photographic reproductions and text illustrations, also 64 wing maps.) Price 10*s*. 6*d*. net.

Vital Records in the Tropics. By P. Granville Edge, Division of Epidemiology and Vital Statistics, London School of Hygiene and Tropical Medicine, University of London. London: George Routledge & Sons, 68 Carter Lane, E.C., 1932. (Pp. xi + 167.) Price 7*s*. 6*d*. net.

Filterable Virus Diseases in Man. By Joseph Fine, M.D., B.Sc., D.P.H. (Glas.), D.T.M. (Liverp.). Edinburgh: E. & S. Livingstone, 16 Teviot Place, 1932. (Pp. 144.) Price 6*s*. net.

Cancer: Civilization's Degeneration. By John Cope. London: H. K. Lewis & Co., 1932. (Pp. xvii + 293, with 55 figures.) Price 15*s*. net.

Humoral Agents in Nervous Activity. With Special Reference to Chromatophores. By G. H. Parker. Cambridge: at the University Press, 1932. (Pp. 79.) Price 6*s*. net.

The Advance of Medicine. By the Right Honourable Lord Moynihan, K.C.M.G., C.B., President Royal College of Surgeons of England. The Romanes Lecture delivered in the Sheldonian Theatre, June 1, 1932. Oxford: at the Clarendon Press, 1932. (Pp. 64.) Price 2*s*. 6*d*. net.

Man and Medicine. An Introduction to Medical Knowledge. By Dr. Henry E. Sigerist, Professor at the University of Leipzig. With an Introduction by Dr. William H. Welch, Professor of the History of Medicine, Johns Hopkins University. London: George Allen & Unwin, Museum Street. (Pp. x + 340.) Price 12*s*. 6*d*. net.

The Physical Mechanism of the Human Mind. By A. C. Douglas, M.B., Ch.B., Hon. Surgeon Dunfermline and West Fife Hospital. Edinburgh: E. & S. Livingstone, 16 Teviot Place, 1932. (Pp. xiv + 251.) Price 15*s*. net.

The Subject Index to Periodicals, 1930. (Pp. ix + 595.) (London: The Library Association, 1932.) Price £3 10*s*.

The value of this annual index is too well known to scientists to need pointing out afresh each year. The work grows larger with every year, and now comprises some 28,000 entries representing articles printed in about 600 different journals, English, American and European. In spite of the fact that the field covered by the specialised abstracting journals is left untouched by the Library Association, the amount of scientific literature noted is very large.—J. W.

Wireless Receivers. The Principles of their Design. By C. W. Oatley, M.A., M.Sc., King's College, London, with a Preface by O. W. Richardson, F.R.S., Yarrow Research Professor of the Royal Society. London: Methuen & Co., 36 Essex Street, W.C. (Pp. vii + 103.) Price 2*s*. 6*d*. net.

Cambridge Excavations in Minorca. Trapuco. Part I. By Margaret A. Murray, D.Lit., F.S.A. (Scot.), F.R.A.I., Fellow of University College, London. With Chapters by Edith M. Guest, M.A., M.D., B.S., C. Ainsworth Mitchell, M.A., D.Sc., F.I.C.P., and T. J. Ward. London: B. Quaritch, 11 Grafton Street, New Bond Street, 1932. (Pp. 50, with 52 plates.) Price 12*s*. 6*d*. net.

Philosophical Aspects of Modern Science. By C. E. M. Joad. London: George Allen & Unwin, Museum Street. (Pp. 344.) Price 10*s*. 6*d*. net.

Perception. By H. H. Price, M.A., B.Sc., Fellow and Lecturer in Philosophy, Trinity College, Oxford. London: Methuen & Co., 36 Essex Street, W.C. (Pp. ix + 332.) Price 12*s*. 6*d*. net.

Philosophy and the Ordinary Man. The Presidential Address (1932) to the British Institute of Philosophy. By Sir Herbert Samuel. London: Kegan Paul, Trench, Trübner & Co., 68 Carter Lane, E.C.4. (Pp. 39.) Price 1*s*. 6*d*. net.

Ten Contemporaries. Notes toward their Definitive Bibliography. By John Gawsworth. With a Foreword by Viscount Esher and original essays by Lascelles Abercrombie, Herbert E. Palmer, George Egerton, Sir Ronald Ross, Stephen Hudson, Edith Sitwell, Wilfrid Gibson, Robert Nichols, Rhys Davies, M. P. Shiel. London: Ernest Benn, 154 Fleet Street, E.C.4. (Pp. 224.) Price 7*s*. 6*d*. net.

Southern Europe. A Regional and Economic Geography of the Mediterranean Lands (Italy, Spain, Portugal, Greece, Albania, and Switzerland). By Marion I. Newbigin, D.Sc. (Lond.). London: Methuen & Co., 36 Essex Street, W.C. (Pp. xvi + 428, with 103 figures.) Price 15*s*. net.

Other-world Stuff. By Charles Whitly, B.A., M.D. (Cantab.). London: Rider & Co., Paternoster House, E.C. (Pp. 221.) Price 7*s*. 6*d*. net.

The Psychology of Consciousness. By C. Daly King, M.A. With an Introduction by Dr. William M. Marston. London: Kegan Paul, Trench, Trübner & Co., 68 Carter Lane, E.C., 1932. (Pp. xv + 256.) Price 12*s*. 6*d*. net.

Cacao. By Dr. C. J. J. van Hall. Second Edition. London: Macmillan & Co., St. Martin's Street, 1932. (Pp. xviii + 514, with 176 figures.) Price 28*s*. net.

Osiris and the Atom. By J. G. Crowther. London: George Routledge & Sons, 68 Carter Lane, 1932. (Pp. viii + 221.) Price 5*s*. net.

Readings from Modern Science. Edited by W. J. Bransom. London: George G. Harrap & Co., 39 Parker St., Kingsway. (Pp. 270.) Price 3*s*. 6*d*. net.

The Social Selection of Human Fertility. By R. A. Fisher, F.R.S. The Herbert Spencer Lecture delivered at Oxford, June 8, 1932. Oxford: at the Clarendon Press, 1932. (Pp. 32.) Price 2*s*. net.

Deserts and the Birth of Civilisations. Does the White Man owe his Being to the Great Deserts? By A. J. McInerny, M.Inst.M.M. (Lond.). London: "Studies" Publications, 8 Breams Buildings, E.C.4. (Pp. 46.) Price 1*s*. 9*d*. net.

Cloud-top Mosaics. By R. and K. Barrett. Cambridge: W. Heffer & Sons, 1932. (Pp. ix + 176.) Price 3*s*. 6*d*. net.

Thermionic Emission. A Survey of Existing Knowledge with Particular Reference to the Filaments of Radio Valves. By W. S. Stiles, Ph.D. London: His Majesty's Stationery Office, 1932. (Pp. 116.) Price 2*s*. 6*d*. net.

The Calendar and its Reform. By F. A. Black, F.R.S.E. London: Gall & Inglis, 13 Henrietta Street, W.C.2; and Edinburgh: 12 Newington Road. (Pp. vii + 80, with 3 plates.) Price 2*s*. 6*d*. net.

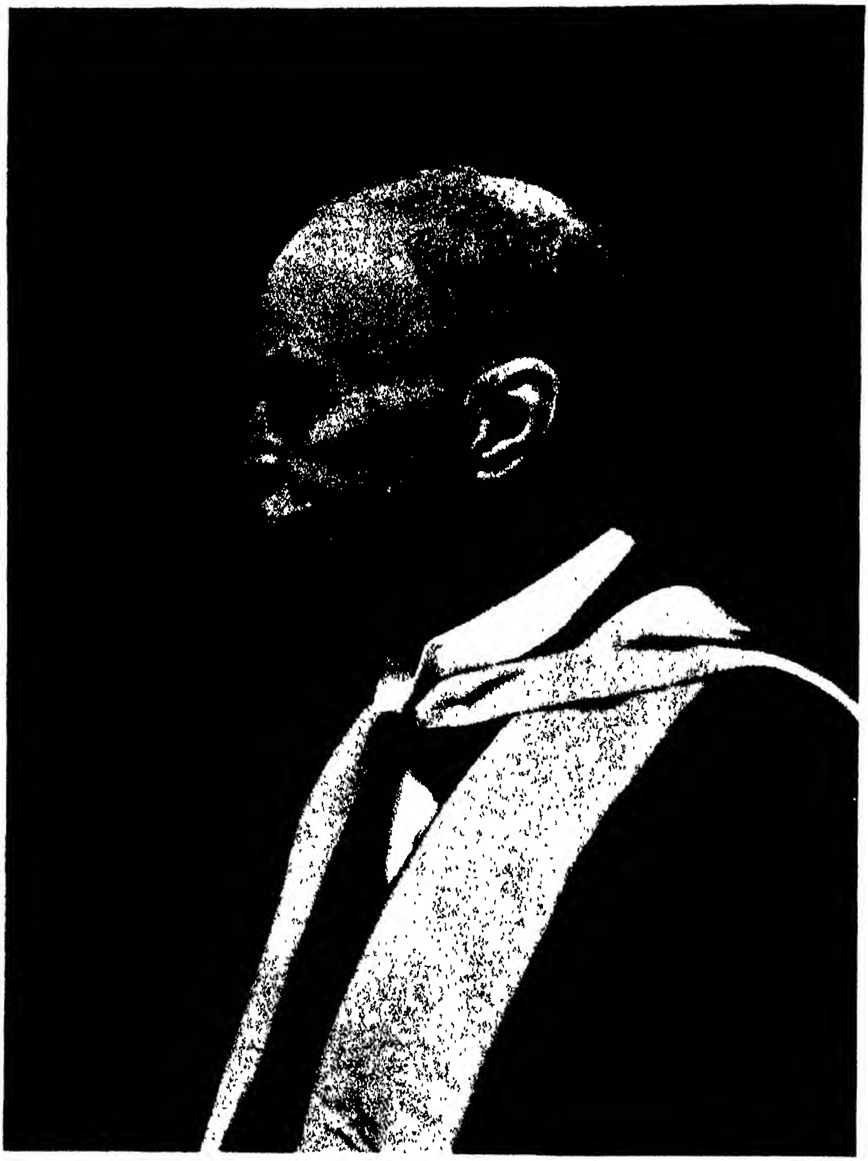
Heredity in the Light of Esoteric Philosophy. By Irene Bastow Hudson, M.R.C.S., L.R.C.P. London: Rider & Co., Paternoster House, E.C. (Pp. 144.) Price 3*s*. 6*d*. net.

Correspondence and Papers of Edmond Halley. Preceded by an Unpublished Memoir of his Life by one of his Contemporaries and the "Éloge" by d'Ortons de Mairan. Arranged and edited by Eugene Fairfield MacPike, Member of the History of Science Society, Oxford Historical Society, etc. Oxford: at the Clarendon Press, 1932. (Pp. xiv + 300.) Price 21*s*. net.

Huxley Memorial Lectures, 1925–1932. London: Macmillan & Co., St. Martin's Street, 1932. (Pp. 172.) Price 2*s*. 6*d*. net.

Vox Naturæ. By Edwin Terbea. London: Arthur H. Stockwell, Ltd., 29 Ludgate Hill, E.C.4. (Pp. 191.) Price 6*s*. net.

Printed in Great Britain by
Hazell, Watson & Viney, Ltd., London and Aylesbury.



[*Reginald Haines.*

COLONEL SIR RONALD ROSS, K.C.B., K.C.M.G., F.R.S., LL.D., M.D., D.Sc., F.R.C.S., D.P.H., L.S.A.

SCIENCE PROGRESS

RONALD ROSS

1857–1932

"For, as I take it, Universal History, the history of what man has accomplished in this world, is at bottom the History of the Great Men who have worked here. They were the leaders of men, these great ones, the modellers, patterns, and in a wide sense creators of whatsoever the general mass of men contrived to do or attain ; all things that we see accomplished in the world are properly the outer material results, the practical realisation and embodiment of Thoughts that dwelt in the Great Men sent into the world ; the soul of the whole world's history, it may justly be considered, were the history of these. Too clearly it is a topic we shall do no justice to in this place !"

"Yet let us say it is at all times difficult to know *what* he is, or how to account for him or receive him !"—CARLYLE.

SIR RONALD ROSS was born on May 13, 1857, at Almora in the Himalayas. At Almora there were peace and pleasant coolness, and the ever-changing views of the snows of the loftiest peaks in the world—a fitting birthplace for one who towered above his fellow-men in his genius, his patience and his high moral courage. Ross came of a family some of whom had served with distinction in India. His father, General Sir Campbell Claye Grant Ross, K.C.B., commanded on the Afghan Frontier when Lord Roberts marched to Kandahar. He was a man of culture, and has left many delightful water-colour sketches of Indian scenery.

Ronald Ross remained in India until 1865. He was educated in a private school in England ; and at the age of seventeen began the study of medicine at St. Bartholomew's Hospital, London. The choice of his profession was made by his father ; the son wished to become an artist. He was, as he tells us, not interested in medicine. At that time his mind was developing on broad lines. He was too deeply concerned with life as a whole to concentrate on the details of a medical curriculum and he attained no distinction in his examination. To some he may have appeared a dreamy lad, late in developing. The tree with fine-grained wood grows slowly. It was not till

many years later that he turned to the study of disease, and then it was to concentrate on its prevention. At the time of which I write he was much more interested in philosophy, poetry, mathematics, and music than in medicine, but on reaching maturity he was in all these branches of science and art far above the average. He attained supreme distinction in one branch of science, but had his father not made him a doctor we can hardly doubt his genius would have won for him a similar distinction in mathematics or philosophy, or have burst into poetry or music that would have added lustre to the annals of our race. "I will remark again, however, as a fact not unimportant to be understood," says Carlyle, "that the different *sphere* constitutes the grand origin of such distinction; that the Hero can be Poet, Prophet, King, Priest, or what you will, according to the kind of world he finds himself born into. I confess I have no notion of a truly great man that could not be *all* sorts of men."

Green Pastures

So we find Ross for ever turning to music and mathematics, and to poetry which is musical thought. Creation was a joy, recreation, and refreshment in which he forgot the worries of life. They were green pastures and still waters. After the serious illness in 1927 which paralysed his left side and limited his activities, he published or republished some of his early romances and poetry. *Philosophies* came out in 1910, *Poems* in 1928, *Fables and Satires* in 1930 and *Lyra Modulata*, written when a student at "Bart's," in 1931. These contain many pieces of moving splendour, mingled with bitter satire, wit, wisdom and imagination. His three romances, *Spirit of Storm*, *Child of Ocean*, and *The Revels of Orsera* show the careful word-painting of one with an observant eye, but there are brilliant passages that some believe to be the best of Ross's writings, better even than his best poetry. *In Exile* records the thoughts and feelings of his early days in India. It has the unique distinction of containing a poem written by the poet-scientist himself on a discovery that made him one of the greatest benefactors of his race—written while the lens of his microscope was still dim with sweat of his travail.

"At His command,
Seeking His secret deeds
With tears and toiling breath,
I find thy cunning seeds,
O million-murdering Death.

"I know this little thing
A myriad men will save.
O Death, where is thy sting,
Thy victory, O Grave!"

The words of a prophet and poet! "Once again the most precious gift that Heaven can give to the Earth; a man of genius, as we call it," was walking among men. A "Great Man," a "Hero" Carlyle would have called him. We shall see how the world is to treat him. Fortunately he is no misty figure in the past. We knew him, some intimately and familiarly: and he has left us documents throbbing with human interest. His poetry tells us much; his letters to Manson show us the "Hero as Scientist" at work; his *Memoirs* fill up the gaps in the story, and give us his thoughts in the evening of his life.

After obtaining his medical qualification, Ross entered the Indian Medical Service, taking a rather low place in the entrance examination, and sailed for India in 1881. His official duties did not occupy his whole time; and his over-ample spare time he filled by working still at his poetry and mathematics and by taking part in the usual sports of the Station. But the misery of life in India, the cruelty of its caste rules, the poverty, famine and death could not fail to cause a reaction in the new recruit, a reaction which became more intense as the years passed.

Can we not Cure?

It was the suffering in the wards of his Indian Hospital that was to bring out the greatness of this Great Man;

> "The painful faces ask, can we not cure?
> We answer, No, not yet; we seek the laws."

They drew him to that deeper study of disease which has attracted so many of the distinguished men of the Indian Medical Service, brought laurels to them, and made that Service the greatest medical service the world has seen. Ross had now found the work of his life. From now on life had for him a definite purpose; the ship had swung to its true course, to which it held as long as life remained. So 1889 found him in London studying the new science of Bacteriology and working for the newly created Diploma of Public Health. "The great heart, the deep-seeing eye" understood that many of the diseases of India were preventable, but preventable only if their cause was understood; that disease was one of the chief causes of poverty; and that of all the diseases malaria was the one which, in the words of the Government of India, is "in many tracts a scourge far greater than either plague or cholera" and that "it maims as well as kills, and causes more sickness, misery, and death than any other single disease." And the researches of others have added to the indictment. "It is directly responsible for an enormous number of deaths

from diarrhœa, dysentery, nephritis, abscesses, convulsions in children, and other diseases due to germs which infect because the vitality of the victim has been lowered by malaria." In his choice of a disease for study, Ross had chosen even more wisely than he knew.

On his return to India he commenced work on malaria. Unable to identify the parasites of the disease described by Laveran, he began to doubt their existence. He fell into error, reached wrong conclusions and, as he says, "All my laborious studies during these years 1890–4 were ineffective." But the time was not entirely wasted. He was learning to use his tools and becoming a master in his craft.

Patrick Manson

Ross's next leave in England in 1894 brought him into contact with Patrick Manson (born in 1844), who with truth has been acclaimed the "Father of Modern Tropical Medicine." Manson's interests were chiefly medical—in the restricted sense of the word—but he had a great heart as well as a great mind. Ross and Manson were irresistibly drawn to each other. Manson placed all his knowledge of malaria at Ross's disposal and with his power and influence was to prove an invaluable ally and a true friend to the younger man in the difficulties that beset him during the next few years when success or failure was to mean so much to humanity.

From his work on *Filaria bancrofti* in China, Manson had become convinced that this parasite escaped from the blood of man by the agency of the mosquito to live outside man; and his studies of the malaria parasite had led him to believe that it also passed part of its life outside the human host. Manson thought that a certain form of the malaria parasite was the first stage of this extra-human existence; that part of this stage was spent in the body of the mosquito, and that on the death of the mosquito the parasite passed into water, and returned to man once again when he drank infected water or inhaled infected dust. Active research on malaria was being pursued in many parts of the world. All the excretions of the malaria patient had been examined, but nowhere had the parasites been found except in the blood of man. Manson convinced Ross that there was a strong *prima facie* case for studying the mosquito, and Ross left for India determined to follow the line of research suggested by Manson.

The point at which the investigation was to begin was the curious writhing thread which bursts from the crescent-shaped parasite some time after blood has been drawn. Most workers believed that this was a death agony, but Manson thought,

and time has proved he was right, that these curious " flagella " were a phase designed to continue the parasite's life outside of its human host, and inside the mosquito.

" Follow the flagellum " was Manson's advice. Unfortunately it proved impossible to " follow the flagellum." It disappeared utterly soon after it entered the mosquito's stomach. Ross could find no trace of it in the insect. But as if he had heard Masefield's song of the watchers of ships—

> " Adventure on, for from the littlest clue
> Has come whatever worth man ever knew ;
> The next to lighten all men may be you . . . ."

with " only one star to steer by, Hope," on he pressed.

Two strenuous years of work brought no result, but in that time Ross acquired a knowledge of the structure of the mosquito and worked out a technique for examining the insect. He toiled all through the hot weather—Indian hot weather I would have you remember—but as failure followed failure he became exasperated and worked till he " could hardly see his way home." He tells us of his " dark, hot, little office " ; he could not use a punkah as it blew away his mosquitoes. " The screws of my microscope were rusted with sweat from my forehead and hands, and its last remaining eyepiece was cracked ! " . . . " I was tired, and what was the use ? I must have examined the stomachs of a thousand mosquitoes by this time. But the Angel of Fate fortunately laid his hand on my head," for under Ross's microscope at that moment was the very thing he sought. He looked—the problem is solved.

The Discovery

He had found two hitherto unknown factors : first where the parasite appeared in the tissues of the mosquito, and what it looked like ; and secondly, the special kind of mosquito in which the parasite was to be found. This appears to me to be the zenith of Ross's genius, for nothing but the eye of genius could have recognised the tiny parasite as it lay among the cells of the stomach of the mosquito. And I would like to emphasise that it was human malaria, and not bird malaria, which he discovered in the mosquito. The solution of the Great Problem —as he calls it—had then been found.

Having discovered these two unknown quantities, the rest of the research presented no difficulties to Ross ; and he would have finished his work in a few weeks but for his unfortunate transfer to a part of India where there was no malaria.

It was some months, even with Manson's influence, before he was able to resume his work on malaria. In Calcutta the great epidemic of plague had raised fear even of the prick of a

needle in the native mind, and Ross, who was now working there, was unable to obtain malaria subjects. At Manson's suggestion he demonstrated the remainder of the life-history of the parasite with the malaria parasite of birds. And what he found was something that neither he nor Manson had anticipated. The parasite which he found growing in the mosquito's stomach ultimately divided into thousands of minute threads; these found their way to the salivary glands of the mosquito; when the mosquito bit man and injected its poison into him, the malaria threads were also injected. The parasite—after passing an essential stage of its life-history outside of man—returned to man by the same route that it left him.

Claims were afterwards made by the Italians that it was they who had proved that human malaria was conveyed by the mosquito, but it cannot be too definitely stated that it was not the Italians, but Ross, and Ross alone, who first discovered that the malaria parasite grew in the mosquito. What the Italians did was to confirm Ross's work on the later stages of the life-history of bird malaria in the mosquito, by repeating his procedure with human malaria. There was nothing really original in what the Italians did. Ross had removed all the difficulties before they began their work; they followed his methods exactly, and simply confirmed his conclusions. Ross's work in 1897–8 was so exact that since then nothing has been added and nothing taken away.

The fundamental discovery of the infection of the mosquito was made on August 20, 1897, at Secunderabad, and the whole work was completed in time for Manson to announce it to the Tropical Section of the British Medical Association at Edinburgh in July 1898. His announcement created "a profound sensation among the members," who stood up and cheered.

The discovery was important not only because it showed how malaria spread; it was hardly less important because it turned men to investigate insects as the carriers of other diseases, and within a few years the germs of yellow fever, relapsing fever, plague, typhus fever and sleeping sickness had all been shown to have insect hosts. Thus does a fundamental discovery open wide the flood-gates of knowledge.

Cost what it Might

Soon afterwards Ross left India. Those who have read his *Memoirs* and have seen the correspondence with his departmental heads which preceded his resignation, will realise that the value of Ross and his work was unfortunately not understood in India. From 1889 his life had been devoted to the discovery of the cause of malaria, so that it might be prevented.

After long and laborious years of work he had achieved success of vital importance to the world. He was now filled with an equal devotion to the cause of preventing the disease. He felt he had no guarantee that in India his time would not be wasted; and, cost him what it might (it cost him half his pension to leave the Service when he did), he was not the man to allow himself to be diverted from what he regarded as a clear duty to the millions who suffered and died from the disease every year throughout the world.

"Think, though you thunder on in might, in pride,
Others may follow fainting, without guide,
Burn out a track way for them; blaze it wide."

On leaving India Ross became Professor of Tropical Medicine at the Liverpool School of Tropical Medicine, and he threw himself whole-heartedly into the work. He paid a number of visits to the tropics, either for the purpose of research, or of advising various Governments on sanitary problems. But he was not particularly happy in Liverpool, partly because he, who had treated thousands of patients suffering from tropical diseases in India, was held not qualified to treat tropical diseases in Liverpool—he was not given beds in the local hospital because he did not possess the degree of Doctor of Medicine—partly because he was underpaid; but mainly because his energies were cramped. Neither Liverpool nor the Empire knew how to use the services this Great Man was straining to put at their disposal. In despair he left Liverpool in 1913.

So he began consulting work in London, and was building up a large practice when the Great War claimed his services as Consultant on Malaria to the War Office.

The Ross Institute

After the War he was Consultant in Tropical Diseases to the Ministry of Pensions, but his health was not good. Later he became Director-in-Chief of the Ross Institute and Hospital for Tropical Diseases in London, with the design of making it a centre of treatment and research, as free as possible from the official control and restraint which had so handicapped him in his earlier life.

The Institute was opened by the Prince of Wales in July 1926. On behalf of the Institute, Ross visited Ceylon in 1925, and Malaya and India in 1926–7. This was his last expedition to the tropics, for at the end of 1927 he became paralysed on his left side. On recovering from the shock, he continued to take a deep interest in the work of the Institute, and in addition devoted much time to mathematical work, particularly the

difficult mathematical problems connected with epidemics. He had become Editor of SCIENCE PROGRESS in 1913, and remained Editor till his death. Its readers are familiar with his views and the work he did for it. Like all great men he held strong views, and he expressed them without fear or favour.

In 1902 Ross received one of the earliest Nobel Prizes, and a few years later a Royal Medal from the Royal Society. Academic honours came to him from all over the world. He was made a Knight Commander of the Bath in 1911, and Knight Commander of St. Michael and St. George in 1918. These things gave Ross pleasure, but he was not a man to whom distinctions of any kind were an end in themselves. The aim and object of his life was to increase the happiness of his fellow-men.

He had proved to his own satisfaction that malaria was preventable in many places, and therefore should be prevented ; but his medical colleagues understood neither his reasons nor his recommendations, and for many years there was a bitter controversy in which he did not spare his opponents.

MOSQUITO REDUCTION MISUNDERSTOOD

There is nothing more astonishing to the writer of this article than the complete misunderstanding of what Ross had recommended as early as 1899.

In my possession is a letter from one of the ablest men (C. W. D.) in the Colonial Service, showing that even he, who had been engaged in malaria research for many years and had been directly associated with Ross in his researches, had never grasped what Ross really meant. From the first Ross had included drainage as one of the methods of reducing the number of mosquitoes and so reducing the amount of malaria. Indeed, the world had during the centuries become aware of the paludic nature of malaria, and the good effect of the drainage of marshes. When confronted with a malaria problem due to swamps and marshes in 1901 at Klang in the Federated Malay States I decided to employ the knowledge given us by Ross. When I had proved the existence of anopheles in the swamps and pools, these were drained by Government, and malaria practically disappeared. Yet the letter to which I have referred, dated August 20, 1903, says : " . . . You have not in the least followed Ross's lines, but acted in opposition to them, as he advocated treatment seriatim of each breeding place and has opposed extensive engineering operations." A few months later, February 11, 1904, I wrote to Ross : " The idea of a quinine prophylaxis was utterly out of the question, and seems to me,

with all due deference to Koch, to be of no value in practical sanitation (over 70,000 immigrants entered the State through Klang and Port Swettenham in 1901, a big order to examine the blood of all). Your method of breaking the malaria circle at the mosquito has been followed here, although for local reasons it seemed to me that the work should be done by the engineers rather than that I should organise mosquito brigades."

Like all pioneers, Ross met with scepticism and neglect. Lister had met with the same before him. The changes in the details of his method which Lister introduced from time to time had confused many of his contemporaries and confirmed them in their unbelief of both the theory and practice of antiseptics. It took a full thirty years to convince the profession as a whole of the scientific foundation and practical value of Lister's system of treating wounds. In one way Ross was more fortunate than Lister. Ross's discovery was a clear-cut piece of work which could be, and was, repeated exactly and its truth demonstrated convincingly. It could not in fact be challenged except by those who were literally blind. From the first it was accepted by Manson, Lister, Daniels, Ray Lankester and other scientific men. But in the practical application of the discovery Ross was at a great disadvantage when compared with Lister. Lister had his cases in his hospital wards, under his own care, and could apply his treatment without considering what other surgeons thought, and without having to obtain their consent and co-operation. His experiments cost nothing, and he could vary them as he pleased and when he pleased. But with Ross it was different. He saw from the first that no one method could control malaria in all conditions in which it occurred. And he stated clearly that for full success further research and experiments were necessary. And although he could not and did not anticipate all the developments which have occurred in malaria control, he realised how much remained to be discovered and gave each new advance a cordial welcome.

As time has shown, the prevention of malaria requires, in addition to a knowledge of the disease, a considerable understanding of the biology of many species of mosquitoes. The larvæ of the various species have very different habits and habitats. Some live in shade, and some in sunshine; some live in dashing mountain streams; to others, a current means death. "Shade and Shine" and a hundred different factors, chemical and physical, affect the insects; they appear and disappear with the rapidity of a transformation scene when these factors are changed. And the malaria dependent on them comes and goes as if obedient to the wand of a magician.

Mosquito reduction also requires a knowledge of land drainage, and of the special refinements of drainage necessary for

anti-malarial work. This was not known thirty years ago when, unfortunately for the world, an official experiment was made in order to test the practicability of preventing malaria by the destruction of mosquitoes. The experiment failed for want of knowledge, but, as Ross wrote to me, "it will put back the hands of the clock in India for a generation."

About the same time Koch suggested that if men took quinine and killed the parasite in their blood, the mosquito could not become infected and malaria would die out. This at once appealed to medical men. Here was a thing they could understand, because they had been trained in curative medicine, not in entomology and engineering. For a whole generation this has been the chief method employed by medical men throughout the world in the prevention of malaria.

To-day men know that quinine cannot do what was once claimed for it, but valuable time and many lives have been lost.

The Sting

Although successful anti-malarial work based on mosquito reduction took place in a few countries, notably in Malaya as far back as 1901, and at Panama in 1904, an acute controversy occurred in which Ross did not spare those who had said his discovery was of no practical value. Most countries, however, made no use of it. How bitterly Ross felt this is seen in his poem—

"THE ANNIVERSARY

(*20th August*, 1917)

"Now twenty years ago
  This day we found the thing;
With science and with skill
  We found; then came the sting—
What we with endless labour won
  The thick world scorned:
Not worth a word to-day—
  Not worth remembering.

"And clapp'd our hands and thought
  Your teeming width would ring,
With our great victory—more
  Than battling hosts can bring.
Ah, well—men laughed,
  The years have pass'd;
The world is cold—
  Some million lives a year,
Not worth remembering!

"... but when true
  Achievement comes—
A trifling doctor's matter—
  No consequence at all!"

The Man Misunderstood

Just as his medical recommendations had been misunderstood, so the man himself was for a time sadly misunderstood. This is recalled in some of the press notices of his death. One suggested he should have taken no notice of what he in trenchant language called " Italian Brigandage." He was accused of being wanting in modesty and reserve, egotistic, asking for praise and money, and to the outside world he often appeared the cynic, satirist, and pugilist.

Such critics do not understand a Great Man as Carlyle did. " There is no Dilettantism " in the Great Man ; " it is a business of Reprobation and Salvation with him ; of time and eternity ; he is in deadly earnest about it ! " " Not a mealy-mouthed man ! A candid ferocity, if the case call for it, is in him ; he does not mince matters ! "

To Ross this was a matter of a million lives a year, and when he found the Temple of Truth filled with liars and robbers, he declared roundly they had made it a den of thieves. It is of the essence of the Great Man that he is sincere. " No, the Great Man does not boast himself sincere, far from that ; perhaps he does not ask himself if he is so ; I would say rather, his sincerity does not depend on himself ; he cannot help being sincere." Ross saw " a world where much is to be done " ; he asks, " Why has it not been done ? " and tells men bluntly they are following a false path and false ideas. " Personal manners, literary criticism, eloquence, sport, party politics, sectarian dogma," are the " modern equivalent of Indian Fakirism, by which, lost in lofty speculations, we are taught to remain content in the midst of starvation and disease." And the results of false ideas of governments are " precisely what may be imagined—cities built without sense or forethought, filthy slums, hovels filled with disease, gulfs of destitution ; and the voices who would better this state of affairs by scientific methods are lost among the yells of the opposing factions." And he tells the medical profession, " It is a body without a head." " The duty of the profession does not lie merely in teaching and the care of the sick, but in everything that appertains to the health of the people " ; and because it is not always dominated by this " lofty ambition "—" it does not take a high enough stand with the public regarding scientific and sanitary matters."

He sums it up : " The history of malaria contains a great lesson for humanity—that we should be more scientific in our habits of thought, and more practical in our habits of government. The neglect of this lesson has already cost many countries an immense loss in life and prosperity." True in 1910—the loss is still greater by 1932.

Scientific Helots

But how was this scientific habit to be attained? Ross has very clear views how. It is no new doctrine that the labourer is worthy of his hire. Ross saw that the research worker was not properly paid, and wrote in his *Memoirs*: "If the world refuses to pay for world service, while it allows anyone to enrich himself by self-service, well, it is the world that suffers for its own folly. . . ." Odd conduct this, some thought, in a man who had received the Nobel Prize, and so many other honours! Hardly decent, lacking in modesty! But false modesty is no part of the make-up of a Great Man. Ross had said over and over again, "I have solved a great problem—one of the world's greatest problems." To have said otherwise would have been insincere and false—and Great Men are neither insincere nor liars. When Ross said "Pay" he was fighting not primarily for himself—he was fighting for others and for good government.

> "Adventure on, and if you suffer, swear
> That the next to venture shall have less to bear;
> Your way will be retrodden, make it fair."

And it was not until the world had turned a deaf ear to his teaching that with dramatic force he quietly offered his archives for sale in Science Progress. For the first time his generation saw the truth, and was shocked to find itself responsible for one more of the tragedies which from time to time have defaced the pages of history. Happily disaster was averted. A fund of money was raised which drove out his anxiety for the future of Lady Ross and gave him pleasure in many ways.

He visits Malaya

A visit to Malaya in 1926 may be regarded as a turning-point in his thoughts. While most of the world had failed to use the knowledge he had given them, Malaya had forged ahead, quietly and steadily, since 1901. The success at Klang and Port Swettenham had shown what could be done, and in 1904 Ross wrote to me: "You have certainly saved the honour of the British people for scientific practical work. . . ." I should like to congratulate you for it. . . . I suppose you have read the wretched failure made at Mian Mir. . . . I fear that experiment will put back the hands of the clock in India for another generation. However, your work may succeed in putting them on again." Of our great successes in Malaya in 1909 he wrote: "Your extension of mosquito reduction to rural areas is great. I have never dared to moot

this, but have always doubted whether quinine alone will do much in the presence of many mosquitoes."

Ross had long desired to visit Malaya, but it was not until 1926 that he was free to gratify his wish. This delay was, for the Empire and the world, a pure tragedy. An illness had undermined his health, and compelled me, much against Ross's wishes, to curtail the programme I had mapped out for him. But no one who heard him in the College of Medicine in Singapore will forget his lecture. It was, as we now know, the last public lecture he was to give. On the walls hung maps and plans of the work, and charts showing how tens of thousands of lives had been saved on the island by the discovery that he had made. They were an inspiration to him. Despite the broiling heat of a Singapore afternoon, for an hour he held in a spell a crowded audience as he told the story of malaria from the times of the Persians and Greeks, through the ages, till that very day when he had seen with his own eyes the triumphs of anti-malarial work both in the urban and rural areas of Singapore. It was an historic hour for the city. How its great founder, Sir Stamford Raffles, would have loved to have been present.

After leaving Singapore he travelled with me for some six hundred miles, visiting towns, villages, estates, native holdings, tin mines, and rice fields. He saw malaria work on a scale that he had not fully realised. It was something like the dreams with which he had left India—"The death pests would begin to come under control, would begin to diminish, even to disappear entirely in favourable spots. . . . Not disappear entirely of course (perhaps an impossible ideal), but be at least banished from the centres of civilisation." As we moved through the country, I showed him the places in which I had worked. I told him how the idea of Biological Control had grown from these researches, and his scientific mind realised more vividly than ever the almost unlimited possibilities in this method of stamping out malaria in places where the task might seem hopeless. But perhaps what comforted him most was to meet a people—officials and unofficials, administrators, medical men, business men, planters, and others throughout the length of the Peninsula—who had not to be convinced of the value of mosquito-malaria control, but who knew its value because they themselves had used it. Never before in his life, as he told me, had he seen this, or met men so advanced in their scientific outlook on the practical affairs of life ; for Malaya had earned the praise given to her medical administration by the late Sir Andrew Balfour, Director of the London School of Hygiene and Tropical Medicine, when he said it is "a story which is a Medical Iliad in its way, and shows what can be done

when the right men and ample funds are forthcoming." And when Ross returned to London he reported to the Committee of the Ross Institute that the work in Malaya was "the greatest sanitary achievement ever accomplished in the British Empire." His sojourn in Malaya was balm to the bruises and wounds of the old fighter. What had been done in Malaya could be done elsewhere. The long night had passed. He had seen with his eyes, not the dawn, but the sun risen on a new day—the day of his dreams; the realisation of what he had toiled for in his "dark, hot, little office" at Secunderabad, had fought for, had suffered for during thirty long and bitter years.

How he felt about it may be learned from his inscription in the copy of *Poems* which he gave me, soon after we next met in England, where I was to take over the malaria work of the Institute from him. The inscription reads: "Sir Malcolm Watson, who proved the piece on page 77 was a damned lie. Ronald Ross, 10th August, 1928." On turning to page 77 I found "The Anniversary, 20th August 1917"—the bitter poem—part of which I have already quoted. The sting had been drawn. At long last he felt he could put off his armour.

A Humble Religious Man

Although to the outside world Ross was the critic, the satirist, and the fighter, he was in fact a kindly, genial, and generous man, in fact over-generous. He was particularly kind to young men, and returned in full measure the help he in his time had received from Manson. Honest himself, he expected it in others, and he was sometimes the victim of knaves. He readily forgave errors, and mistakes, but never treachery, and to the end he was bitter against some who had played him false. Happily they were few. Treachery was to him the unforgivable sin, as it must be to the Great Man whose essence is Sincerity.

At table—and he came daily to lunch at the Institute as long as he was able—his talk was usually instructive, and always entertaining, for he had travelled widely and observed critically. The meal was never dull. It was often illuminated by flashes of the wit and imagination that adorn his literary work. There was absolutely not a trace of the unapproachableness with which some lesser men surround themselves. Chaff and good humour in which everyone joined always spiced the meal. The visitor was rapidly put at ease, for he found Ross a humble man—

> "Before Thy feet I fall,
> Lord who made high my fate,"

are words from his own Hymn of Praise. And it was at his

Lord's feet in truth and humility he stayed, till He called him to rise.

Ross married in 1889 Miss Rosa Bloxam, who proved a devoted wife and shared with him the early and difficult years in India. There were two sons and two daughters. The eldest son was killed in action during the retreat from Mons. A beloved daughter died in 1925. The death of his wife in September 1931 was a heavy blow under which he slowly sank. After her death he came to live at the Institute, where he received devoted attention and loving care from Miss Gray the Matron, and the other members of the nursing staff.

A Life that cannot End

He was patient in pain—happily in the last few weeks there was almost none, only increasing weakness. But despite his weakness there was the same solicitude for the happiness of others that had guided his life. The last letter he signed was addressed to me when I was in Africa. He was afraid he would not live until I returned, and he wished to explain something I might not have understood—something that would have made me unhappy. I could assure him, I understood perfectly; but he spoke of it again a week before he died. On September 15 his weakness increased rapidly. He had no fear of death. He slept most of the next afternoon, and it seemed as if he would pass away in his sleep. But about seven o'clock he awoke, smiled, and said, perhaps because he felt the days of seeing as through a glass darkly had come to an end,—" I shall find out things—yes—yes." And then he died.

His long illness had been followed sympathetically by the public throughout the world; and there had been touching suggestions of what might help him from many who were strangers. For the world now saw something of the stature of the man, and knew the common phrase would have more than the common truth: " How much poorer the world is by his death."

He died at the Ross Institute on Friday, September 16, 1932, and a few days later was buried, by his express wish, beside his wife.

> " A little hour is given to apprehend
> Divine companions from the mortal friend,
> From mortal hearts a life that cannot end."

Malcolm Watson.

Copy of a letter from General Gorgas to Sir Ronald Ross in 1914.

HYDE PARK HOTEL,
KNIGHTSBRIDGE,
LONDON, ENGLAND.
March 23rd, 1914.

MY DEAR SIR RONALD,

Before leaving England I wish to express to you the debt of gratitude we all feel to you for the great work you have done in the field of Tropical Medicine. As you are aware Malaria was the great disease that incapacitated the working forces at Panama before our day. If we had known no more about the sanitation of Malaria than the French did, I do not think we could have done any better than they did. Your discovery that the mosquito transferred the malaria parasite from man to man has enabled us at Panama to hold in check this disease, and to eradicate it entirely from most points on the Isthmus where our forces were engaged.

It seems to me not extreme, therefore, to say that it was your discovery of this fact that has enabled us to build the Canal at the Isthmus of Panama.

As this is an expression of my personal opinion as to the great value your important work has been to us in sanitation at Panama, you are at liberty to use this letter in any way you please.

With kindest regards and best wishes, I remain,

Yours sincerely,

(Signed) W. C. GORGAS.

SIR RONALD ROSS,
18, Cavendish Square,
London, W.

MAJOR RONALD ROSS I.M.S.

Taken in Darjeeling May 1898 with Diagnostic Microscope invented by him

[Fox Photos.

SIR RONALD ROSS.

Taken for the Medallion on the Gate of Commemoration at the General Hospital of Sir Ronald Ross's old Laboratory Calcutta, opened by Lord Lytton Governor of Bengal January 1926.

RONALD ROSS AS A POET

BY LASCELLES ABERCROMBIE

MEN of science have often had keen and deep artistic interests. Indeed, the scientific mind is much more likely to be interested in the arts than the artistic mind in the sciences. But Ronald Ross was not a mind to be classified under one of our convenient departmental headings. Science gave him a profoundly æsthetic satisfaction, and art for him was but a transvaluation of scientific truth. When the poet in him saluted the Unknown Power, it was in these noble terms :

> " He is the Lord of Light ;
> He is the Thing That Is ;
> He sends the seeing sight ;
> And the right mind is His."

The Thing That Is—the seeing sight—the right mind : whatever was precious to the scientist was precious to the poet ; scientist and poet differed only in expression. The result is something unique in our literature.

Restless, eager, inquisitive, ingenious, and withal unwearying and rigorously determined—these were but the surface qualities of a mind essentially creative. Avid of fact, impatient to penetrate the significance of fact, equally impatient of any significance that could not be verified : thus the scientist created something of the world he desired, a world of exquisitely accommodated interrelationship out of the apparently irrational chance-medley of things ; and thereby incalculably benefited humanity. But this was not enough. The creative energy in Ronald Ross must be poet as well as scientist. Now many men have poetic sensibilities, intuitions, fancies ; but that does not make them poets. The remarkable thing in Ross was that he had mastered the technique of poetry as thoroughly as he had mastered the technique of science ; and poetic technique is no more a mere external activity than scientific technique : the mastery of either can only proceed from a perfected habit of mind. They are totally different habits ; but in Ross they both sprang from one central source.

Ross as a poet is not to be judged as a scientist who had a cultured taste for versifying ; he is to be judged as a poet

writing poetry. In those apparently simple lines quoted above, no one accustomed to estimate poetic art could fail to detect the hand of a master. When Mr. Marsh published his famous first volume of *Georgian Poetry*, intended to represent the new voice in poetry, Ronald Ross was one of the chosen contributors. It was not as a poetic scientist that he was chosen, but simply because his poetry was eminent as such. As it was then, it is now, and, we may be pretty sure, will continue to be. But the peculiar, indeed the unique, quality of his poetry will always be this: that it is the poetry of one who was both scientist and poet. Those (there will always be some) whose appetite for poetry is insatiable will read all of him; but the remarkable sequence of lyrics called " In Exile " will surely stand as one of the acknowledged masterpieces of modern poetry. Here the poet most closely accompanies the scientist; and here too his poetic technique is most his own, equally notable for its terse concision and its command over the inmost power of words:

> "Deep, deep in league with Fate,
> Fate fast in league with Sorrow,
> And Sorrow with my state,
> I would that I could borrow,
>
> "O Deep, a depth from thee,
> O Fate, thy fixèd calm,
> O Sorrow, what to me
> Thou givest not, thy balm;
>
> "That I might worthier show
> A scorn of your controls,
> And let Misfortune know
> Iron chains make iron souls."

" In Exile " is the poetic commentary on one of the most momentous researches in the history of science. No reader will fail to respond to the dramatic splendour of its climax:

> "This day relenting God
> Hath placed within my hand
> A wondrous thing; and God
> Be praised."

The lines are well known; they have often been quoted. But the poem is not called " In Exile " for nothing. With singular power, and memorable emphasis, it describes the dreadful tyranny of tropical nature, which holds captive, body, mind, and spirit:

> "A Land of clamorous cries;
> Of everlasting light;
> Of noises in the skies
> And noises in the night."

"There is no night; the Sun
Lives thro' the night again;
The image of the Sun
Is burnt upon the brain."

Here must the exile live in close companionship with human misery:

"A race of wretches caught
Between the palms of Need
And rub'd to utter naught,
The chaff of human seed."

There are moments of despair; there are moments of resignation and "blind hope":

"So one in prison thrust;
He ages span by span,
But in the prison dust
Becomes a better man.

So one is blind from birth;
All day he sitteth still;
He cannot see the earth,
But heaven when he will."

But through many changes of mood, the faith of the scientist maintains itself: the peak can be climbed, and shall be! And at last comes the reward, and the crowning vision. Thus the poem is more than a personal record—more even than an impassioned meditation on the duties and privileges of science in this divine world. It is a poetic philosophy of life, nobly written, the thought and feeling and imagery of which will stand as solid art when much that is more talked about to-day has gone for ever.

RECENT ADVANCES IN SCIENCE

MATHEMATICAL PHYSICS. By Prof. G. Temple, Ph.D., D.Sc., University of London, King's College.

This review is a continuation of the survey of Eddington's researches in the quantum theory, which was introduced in the last number of *Science Abstracts* by a summary of the relevant mathematical analysis. The present article deals with the physical applications of the theory.

The Idea of a "System."—The fundamental idea of the quantum theory is the concept of a "system," *i.e.* a set of physical entities which can be studied without reference to the other physical entities not included in this set. It is clear that a finite intelligence can only gain knowledge of the external world by isolating systems from the surrounding universe, and it is equally clear that the knowledge so gained is inevitably partial and limited in character. This appears to be the epistemological ground of the principle of uncertainty. Eddington has pointed out (ref. **8**, 332) that the mathematical treatment of the historical development of a system is only rendered possible by treating the system as a whole and by referring the changes in the system to a proper time which is a variable independent of the co-ordinates specifying the system. It is therefore necessary to distinguish between the "public" time of a system and the "private" times of its component parts. This concept of time as the reference scale of change is a faithful mathematical representation of the Aristotelian notion of time —"tempus nihil aliud est quam numerus motus secundum prius et posterius."

The Interaction of Two Systems.—The isolation of a system from its environment is a mental isolation by which a part is treated as a whole. Hence it is possible, in thought if not in reality, to break up a given system S into sub-systems S_1, S_2, . . . and to consider these sub-systems as isolated systems. As isolated systems S_1, S_2, . . . will possess their own public times extending over their component parts, and, as components of the original given systems S they will fall under the public time of S. Now the order of knowledge reverses the natural order of being. We begin with the theory of one particle and then pass on to consider a system of two particles. In this

passage from a consideration of two isolated systems S_1, S_2, to a single system S composed of S_1 and S_2, the public times of S_1 and S_2 are eliminated and replaced by the public times of S. According to Eddington, the transformation involved in this passage introduces into the wave equation the terms recognised as interaction energy (refs. **2**, 711, **3**, 322).

Simultaneity and Relativity.—It is an immediate consequence of the preceding considerations that simultaneity can be reconciled with relativity. By treating a system as a whole and referring its changes to its public time we implicitly introduce simultaneity in different parts of the system, and this simultaneity has an absolute significance. But on breaking up the system into its component particles we have to consider the private times of each particle, and for these private times the relativistic transformations are valid (ref. **3**, 321).

The universe as a whole furnishes the perfect example of a system both mentally and really self-complete. Hence there is a public time measuring the changes in the whole universe and providing the absolute standard of simultaneity. But this " cosmic " time does not supersede public times of smaller systems when these are individually the objects of our study.

The Wave Equation for One Particle—Geometrical Theory.—The starting-point of Eddington's theory is the recognition of the fact that the wave function ψ is a matrix of one column with four elements ψ_1, ψ_2, ψ_3, ψ_4 (such an entity is called a ψ-vector). This fact is accepted without inquiry or explanation. It is, however, clearly associated with the fact that according to relativistic theory the time axis is drawn in different directions by different observers. In classical theory, with a unique time axis, the single wave function of Schrödinger is related to the probability that the particle will be located in the volume $dxdydz$ at x, y, z. But in relativistic theory we must consider, as on an equal footing, the four probabilities that the world-line of the particle will intersect the hyper-surface elements $dxdydz$, $dydzdt$, $dzdxdt$, $dxdydt$. These four probabilities are the probability density and the components of the probability current. It is, at least, plausible that the existence of these four probabilities implies that the wave function ψ has the structure postulated by Eddington on the basis of Dirac's heuristic investigations.

It has been emphasised by Darwin that ψ-vectors cannot be expressed in terms of space vectors. On the other hand, Eddington has shown that space vectors and tensors can be reached from a calculus of ψ-vectors. He therefore begins with the transformation theory of ψ-vectors summarised in the previous article.

The linear transformations of ψ-vectors are specified by

matrices of four rows and columns, and any such matrix is therefore expressible as a linear function of the sixteen matrices $\{E_{\mu\nu}\}$ of a "complete set," *e.g.*:

$$Q = \cos \tfrac{1}{2}\theta + \sin \tfrac{1}{2}\theta \cdot E_{\mu\nu}$$

The outer product of two ψ-vectors, $\psi\psi^{\dagger}$, forms a matrix T whose μ, ν—element is $\psi_{\mu}\psi_{\nu}^{*}$. This matrix represents a ψ-tensor. If the ψ-vector is transformed according to the law

$$\psi' = Q\psi,$$

the ψ-tensor is transformed according to the law,

$$T' = QTQ\dagger,$$

since the $E_{\mu\nu}$'s are skew matrices. Hence to any group of transformations of a ψ-vector there corresponds a group of transformations of a ψ-tensor.

If a ψ-tensor T is expressed in the form,

$$T = \Sigma\, t_{\mu\nu}\, E_{\mu\nu},$$

the sixteen numerical coefficients, $t_{\mu\nu}$, called the matrix components of T, can be regarded as the co-ordinates of a point (in 16-dimensional space) which represents the ψ-tensor T. The transformations of the ψ-tensor induce corresponding transformations in this 16-space, and certain regions of this 16-space will remain invariant under any such group of transformations. These regions will be linear manifolds with only one, two, . . . dimensions. If T is a ψ-tensor whose representative point lies in such a region, the only surviving matrix components of T will refer to the co-ordinates extending over this region and will equal in number the dimensions of this region.

This suggests the problem of determining the group of transformations of a ψ-tensor which makes the number of dimensions of the invariant region a maximum. It is clearly sufficient to consider only infinitesimal transformations, with matrices of the form

$$Q = 1 + \tfrac{1}{2}\theta \cdot E_{\mu\nu},$$

θ being an infinitesimal. Eddington has proved (ref. **1**, 529) that the maximum number of dimensions of the invariant region is five, and that the corresponding group of transformations is generated by five infinitesimal operators, $1 + \tfrac{1}{2}\theta \cdot E_{\mu}$, ($\mu = 1, 2, 3, 4, 5$), for which the five E_{μ} form a perpendicular set.

If T is a ψ-tensor whose only non-zero matrix components are t_1, t_2, t_3, t_4, t_5, these components will behave like an

ordinary space vector in the 5-dimensional invariant region. The transformations of this vector are built up of circular rotations in t_1, t_2, t_3 and in t_4, t_5, and of hyperbolic rotations or Lorentz transformations between these two groups of co-ordinates. Hence the invariant 5-space is like the space-time of relativity with an extra time-like dimension.

To identify this 5-space it must be remembered that a completely isolated particle cannot be a subject for experimental physics. The simplest entity is a particle regarded as part of the whole universe. From this viewpoint there will be two times to consider—the private time of the particle and the cosmic time of the universe. Hence Eddington identifies the invariant 5-space constructed above with the ordinary space-time plus cosmic time.

The form of the wave equation is now decided by the fact that it must be a differential tensor equation of the form

$$W\psi = 0$$

which must be invariant for all the permissible ψ-transformations. Hence W must have the form

$$\left(E_1 \frac{\partial}{\partial x_1} + E_2 \frac{\partial}{\partial x_2} + E_3 \frac{\partial}{\partial x_3} + E_4 \frac{\partial}{\partial x_4} + E_5 \frac{\partial}{\partial x_5}\right),$$

whence $x_4 = ict$, $x_5 = icw$, t and w being real times.

If the particle is in a stationary state $\partial\psi/\partial x_5 = 0$ and only four terms survive. Hence the equation may be re-written

$$\left(E_{15} \frac{\partial}{\partial x_1} + \dots + E_{45} \frac{\partial}{\partial x_4}\right)\psi = 0.$$

It is shown below that the fifth term in Dirac's wave equation represents the interaction of the particle with the universe.

The Wave Equation for one Particle—Dynamical Theory.—Another avenue of approach to the wave equation is suggested by the theory of wave tensors (ref. 8), *i.e.* ψ-tensors, J,f or which

$$j_{16} = -\tfrac{1}{2}\, i\, (\psi_1{}^*\psi_1 + \dots + \psi_4{}^*\psi_4) = 0.$$

If the components j_1, j_2, j_3, j_4, j_5 of J are prescribed, the two factors of J, ψ and $\psi^\dagger$, are partly determined by the equations

$$(j_1E_1 + \dots + j_5E_5)\,\psi = 0,$$

and $$\psi^\dagger(j_1E_1 + \dots + j_5E_5) = 0.$$

These equations closely resemble Dirac's wave equation, but here the j's are ordinary numbers, whereas in Dirac's equation the coefficients of the E's are differential operators.

As was explained in the last article, the wave tensor J is equivalent to two 4-vectors X and P which are at right angles.

Eddington interprets this fact by regarding X as a positional vector and P as a conjugate momentum vector. The orthogonality of X and P then appears to imply that positional relations are only obtainable in the 3-space orthogonal to P. This is in harmony with the general principle of indeterminacy and suggests Eddington's theory of public and private time. The 6-vector S, obtained from the vector product of X and P, is associated with the electric and magnetic moments due to spin.

The Interaction of Two Electrons.—Two electrons may be regarded as two isolated systems or as the components of a single system. In the first case the wave functions for two electrons without interaction must be products of the wave functions for the electrons taken separately, and the corresponding wave equation will be

$$(W + W')\,\psi = 0$$

where

$$W = E_{15}\frac{\partial}{\partial x_1} + E_{25}\frac{\partial}{\partial x_2} + E_{35}\frac{\partial}{\partial x_3} + E_{45}\frac{\partial}{\partial x_4},$$

and

$$W' = E'_{15}\frac{\partial}{\partial x'_1} + E'_{25}\frac{\partial}{\partial x'_2} + E'_{35}\frac{\partial}{\partial x'_3} + E'_{45}\frac{\partial}{\partial x'_4}.$$

If the two electrons are regarded as forming one system, we must identify the domains of the two sets of co-ordinates (x_1, x_2, x_3, x_4) and (x'_1, x'_2, x'_3, x'_4). This identification leads to a certain "principle of equivalence" (ref. 2, 712). A change in the second set of co-ordinates $(dx'_1, dx'_2, dx'_3, dx'_4)$ arising from the displacement of the second electron must be equivalent to some change in the first set of co-ordinates, arising from a quasi-rotation of the first co-ordinate system, and vice versa. This quasi-rotation is

$$\begin{aligned} &dx_1 = x'_5 d\theta_1 \quad dx_2 = x'_5 d\theta_2 \quad dx_3 = x'_5 d\theta_3 \\ &dx_4 = x'_5 d\theta_4 \quad dx_5 = x'_1 d\theta_1 + x'_2 d\theta_2 + x'_3 d\theta_3 + x'_4 d\theta_4 \end{aligned}$$

with $d\theta_\mu = dx'_\mu / x'_5$ $(\mu = 1, 2, 3, 4)$. (refs. 2, 703, 713, 8, 321).

The corresponding transformation of the ψ-vector is

$$d\psi = -\tfrac{1}{2}\,(E_{15}d\theta_1 + E_{25}d\theta_2 + E_{35}d\theta_3 + E_{45}d\theta_4)\,.\,\psi.$$

Hence, if ψ_i and ψ_u are the wave functions for the two electrons regarded as isolated and united respectively,

$$\psi_i(x_\mu\,;\,x'_\mu + dx'_\mu) = \left\{1 - \frac{1}{2x'_5}\,(E_{15}dx'_1 + \ldots + E_{45}dx'_4)\right\}\psi_u(x_\mu\,;\,x'_\mu)$$

therefore

$$\frac{\partial\psi_i}{\partial x'_\mu} = \frac{\partial\psi_u}{\partial x'_\mu} - \frac{E_{\mu 5}}{2x_5'}\,\psi_u.$$

Hence the equation satisfied by ψ_u is

$$(W + W' + I)\,\psi_u = 0,$$

where

$$I = -\frac{1}{2x'_5}(E_{15}E'_{15} + E_{25}E'_{25} + E_{35}E'_{35} + E_{45}E'_{45}).$$

This is the interaction operator.

In order that (x_1, x_2, x_3, x_4) may not be changed by the quasi-rotation we must have $x_5 = 0$. This suggests that the x'_5 in the denominator of I is the cosmic time interval occupied by the transmission of interaction, *i.e.* that x'_5 is proportional to the distance r between the electrons. The form of the interaction operator I then agrees with that devised by J. A. Gaunt. Unfortunately the theory does not eliminate the two proper times x_4 and x'_4, from the equation, and, to this extent at least, it requires modification.

The Fine Structure Constant.—To make the wave equation so constructed agree with experiment, as summarised in Gaunt's equation, it is necessary to write $x_4 = x_4'$, and $x_5' = r/2\alpha$ where α is the "fine structure constant," $2\pi e^2/hc$, with a numerical value of about $1/137$. Eddington has given a subtle but not entirely convincing argument to prove that $2x_5' = 137r$. Only the general principle of the reasoning will be summarised here—namely, the origin of the mystic number 137.

The ψ-vector for two electrons is subject, not only to the transformations specified by the sixteen operators,

$$\cos \tfrac{1}{2}\theta + \sin \tfrac{1}{2}\theta \,.\, E_{\mu\nu},$$

but also to the 256 transformations specified by

$$\cos \tfrac{1}{2}\theta + \sin \tfrac{1}{2}\theta \,.\, E_{\mu\nu}\, E'_{\sigma\tau}.$$

The most general infinitesimal transformation of ψ is

$$\begin{aligned}\psi' &= \psi + \Sigma\theta_{\mu\nu}\, F_\mu\, F_\nu' \,.\, \psi \\ &= \psi + \tfrac{1}{2}\Sigma\{\gamma_{\mu\nu}\,(\theta_{\mu\nu} + \theta_{\mu\nu}) + \zeta_{\mu\nu}\,(\theta_{\nu\mu} - \theta_{\nu\mu})\} \,.\, \psi\end{aligned}$$

where

$$\gamma_{\mu\nu} = \tfrac{1}{2}(F_\mu F_\nu' + F_\nu F_\mu'),\ \xi_{\mu\nu} = \tfrac{1}{2}(F_\mu F_\nu' - F_\nu F_\mu'),$$

using the single suffix rotation for the E's. The γ-transformations are distinguished by the fact that if ψ is symmetrical or anti-symmetrical in the co-ordinates of the two electrons, this characteristic is preserved by the transformation. The ξ-transformations destroy this feature of ψ. Now the presence of r in the denominator of the interaction operator and the identification of x_4 and x'_4 exclude all rotations of the wave equation save those which are antisymmetrical. Hence only the γ-

transformations are admissible and the number of these is $16 + \frac{1}{2} . 16 . 15 = 136$ (ref. 2, 708).

A further distinct type of transformation arises, according to Eddington, from the variation of the distance r between the electrons, and this brings up the total number of transformations to 137.

The Cosmical Constant.—Eddington derives the fifth term in Dirac's wave equation $(2\pi mc/h)$ from the interaction of an electron with all the other changes in the universe Since the E's and E''s form two perpendicular sets, the interaction operator for a single pair of electrons satisfies the equation

$$I^2 = 4\alpha^2/r^2,$$

and its proper values are $\pm 2\alpha/r$.

For N electrons the total interaction operator will satisfy the equation

$$I^2 = 4\alpha^2\Sigma(1/r^2) = 4N\alpha^2/R,$$

and its proper values will be $\pm 2\sqrt{N}\alpha/R$ where R is a mean value of r averaged over all the electrons and presumably of the same order of magnitude as the radius of curvature of the Einstein static universe. This leads to the identification of $(2\pi mc/h)$ with $2\sqrt{N} \cdot \alpha/R$, or a number of the same order of magnitude.

By a modification of this argument Eddington derives the equation

$$2\pi mc/h = \sqrt{N} . \alpha/R.$$

The theory of the Einstein universe gives

$$GNM/c^2 = \tfrac{1}{2}\pi R,$$

where G is the constant of gravitation, M the mass of a proton and N the number of protons in the universe.

Hence the cosmical constant is

$$\frac{1}{R^2} = \left(\frac{2GM}{\pi}\right)^2 . \left(\frac{2\pi mc}{h\alpha}\right)^4$$

The value of $1/R^2$ calculated from this equation is in fair agreement with that inferred from the apparent speed of recession of distant bodies (ref. 4).

The Mass of the Proton.—The wave equation for one electron should accordingly be written as

$$\left(E_{15}\frac{\partial}{\partial x_1} + \ . \ . \ . + E_{45}\frac{\partial}{\partial x_4}\right)\psi = \frac{2\pi \iota mc}{h}\psi.$$
$$= \frac{\iota\alpha\sqrt{N}}{R}\psi.$$

By taking $R/\sqrt{N}$ as the natural unit of length, and by taking α to be $1/136$, this equation becomes

$$\left\{136\iota\left(E_{15}\frac{\partial}{\partial x_1}+\ldots\right)+1\right\}\psi=0.$$

On the other hand, the Schrödinger-Gordon equation for a neutral particle of mass μ is in ordinary rotation

$$\left(E_{15}\frac{\partial}{\partial x_1}+\ldots\right)^2\psi=-\frac{(2\pi\mu c)^2}{h}\psi$$

or say,

$$\left\{\beta\left(\iota E_{15}\frac{\partial}{\partial x_1}+\ldots\right)^2+1\right\}\psi=0,$$

in " natural " units.

Eddington suggests (ref. 5) that just as the linear equation refers to an electrical particle with 136 degrees of freedom for each particle with which it interacts, so also the quadratic equation refers to a neutron with 10 degrees of freedom for the transformations of its associated space-time. Hence $\beta=10$.

Again, this may imply that the first term in each equation represents electrical and mechanical energy respectively. If this is so, the full wave equation for an electrical particle should be

$$\left\{10\left(\iota E_{15}\frac{\partial}{\partial x_1}+\ldots\right)^2+136\left(\iota E_{15}\frac{\partial}{\partial x_1}+\ldots\right)+1\right\}\psi=0.$$

This equation is resoluble into two linear factors of the form

$$\left\{\lambda\left(\iota E_{15}\frac{\partial}{\partial x_1}+\ldots\right)+1\right\}\psi=0,$$

where λ satisfies the equation

$$\lambda^2-136\lambda+10=0.$$

The roots of this are 135·9264 and 0·0735692. Hence the equation corresponding to the first root is effectively the same as the linear equation with which we started.

The other equation corresponds to a particle of mass greater than the electron in the ratio

$$135{\cdot}9264 : 0{\cdot}0735692 = 1847{\cdot}60.$$

This agrees closely with the mass of the proton in electronic units, and a closer examination of the effect of interaction terms

in the equation verifies the fact that the particle described by the second equation has a change $+ e$.

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ASTRONOMY. By R. W. Wrigley, M.A., Royal Observatory, Edinburgh.

Double Stars.—The publication of the *New General Catalogue of Double Stars within* 120 *degrees of the North Pole*, by Dr. R. G. Aitken, marks an epoch in the history of double-star observation. Burnham produced his General Catalogue in 1906, and thereafter he continued to collect references to all measures and orbits of double stars published too late to be included in that work. In 1912 he handed over all his material to Prof. Eric Doolittle, who carried on the tabulation of all new measures and discoveries until his death eight years later, when Dr. Aitken came into possession of his card catalogues and other literature. All available material up to March 1927 has now been included in two large volumes comprising nearly 1,500 pages and cataloguing no less than 17,180 double stars. They have been published under the auspices of the Carnegie Institution of Washington, and will be found invaluable both to the observer who wishes to arrange a workable and useful programme, and to the computer of double-star orbits. In order to confine his entries as far as possible to pairs of stars in actual physical relationship Dr. Aitken has adopted the limiting curve log (distance in seconds) $= 2{\cdot}8 - 0{\cdot}2 \times$ magnitude, which gives an angular separation of 10 seconds for a pair whose combined magnitude is 9·0. This is a generous limit, and the smaller constant 2·5 is now generally adopted for new discoveries, but it has resulted in the exclusion of nearly one-third of the 13,665 pairs listed in Burnham's Catalogue, while it is calculated that the whole sky contains some 27,000 visual pairs which satisfy the condition. It was of course impossible to print every individual measure, and the author has adopted the plan of combining all the available material into weighted means for time intervals chosen with due regard to the star motions. The star places are reduced to two epochs, 1900·0 and 1950·0. The first measure after discovery is always given, followed by weighted means utilising all known measures except those listed in Burnham's Catalogue, and Aitken's knowledge and experience entitle his methods of weighting to be accepted with full confidence. Thus these volumes in

conjunction with Burnham's give a complete record of all the work done on northern double stars, a similar service for the southern hemisphere being done by Innes's Southern Catalogue. The magnitude of each star and the spectral type (if known) are also given, and the measures are supplemented by notes on any available information such as proper motion, parallax, and radial velocity. A bibliography is also given, including all papers on the subject published between 1905 and 1927.

In his George Darwin Lecture, *Monthly Notices R.A.S.*, May 1932, Dr. Aitken summarises our present knowledge of double stars, and shows the value of the prodigious amount of material which has been collected. Among stars as bright as magnitude 9·0, one in every eighteen is a close double within the resolving power of modern telescopes. Convincing evidence has been obtained of the actual orbital motion of 1,495 pairs, one-third of which are of spectral class G, but accurate orbits can as yet be computed only for a small fraction of this number. These visual systems, in conjunction with parallax determinations, afford the only direct observational values of stellar masses, while measures of spectroscopic binaries give the mass ratios of their components but not the masses themselves. An interesting correlation has been noticed between the spectral class and the mass of a system, the latter showing a steady diminution as the former advances from B and A to G, K, and M. It has also been established that the eccentricities of the orbits increase with the periods, the short-period spectroscopic orbits being nearly circular, and the longest-period visual orbits being greatly elongated ellipses. These facts are doubtless related in some way to the mode of origin and evolution of binary star systems, in the entire series of which there seems to be no definite evidence of discontinuity.

In the *Astrophysical Journal*, vol. LXXV, No. 2, W. Markowitz reviews the present-day theories of their evolution: (1) condensations around separate nuclei in a nebula; (2) fission of stars; (3) action of a resisting medium; (4) growth of a planetary system. He assumes that the only forces which can influence the period, semi-major axis, and eccentricity of a binary system are those due to (1) tides; (2) perturbations by other stellar systems; (3) friction in a resisting medium; (4) secular decrease of mass. The effects of these forces are discussed in detail, and evidence is produced that none of them is sufficient to cause the changes necessary to transform short-period spectroscopic binaries into long-period visual systems. The average mass of the latter is apparently not much smaller than that of the former, and it therefore seems that a secular decrease in mass cannot be responsible for

lengthening the periods. Further, a resisting medium would tend to produce a decrease in both period and eccentricity even if the binary in question were losing as much mass by radiation as it was picking up, while the fact that such a large proportion of known systems with periods between 100 and 400 days have small eccentricities suggests that stellar encounters have not been responsible for changing them from long-period doubles. Markowitz considers it probable that all binaries had a similar origin, and that, unless there are other unknown and unconsidered forces in action, the periods, semi-major axes, and eccentricities of the orbits are all tending to decrease, the order of evolutionary development being from long-period to short-period systems. The paper raises many interesting questions, such as the average density of interstellar matter, and whether it is sufficiently high to enable stars to pick up enough mass to provide compensation for their loss by radiation, and thus to maintain approximate equilibrium. But its conclusions will hardly secure general acceptance without further evidence.

Visual measures with the filar micrometer have hitherto been responsible for the great bulk of the material relating to double stars, and they are still essential for dealing with the very close pairs which are generally the most interesting and important. But Hertzsprung and other investigators have demonstrated the value of photography for providing accurate and consistent measures of pairs whose images do not overlap upon the plate, and with large telescopes excellent results have been obtained with an angular separation not exceeding one second when the components have been fairly equal in brightness. Two lists of photographic measures have lately been published by W. M. Smart in *Monthly Notices R.A.S.*, vol. XCII, pp. 37 and 207. The photographs were taken with the Sheepshanks Equatorial Coudé at Cambridge Observatory, the scale being 1 mm. = 35″·2, and were originally obtained for parallax and proper motion determinations. Measures of 440 double stars are given, and, with a few exceptions, the distances all exceed three seconds. Dr. Smart considers that the results are comparable in accuracy with the best visual observations even with so small a separation as this. In order therefore to achieve the most rapid progress it seems advisable for the visual observer to concentrate his attention on the very close pairs, and leave the rest to be dealt with by photographic methods, preferably, of course, with large instruments.

Stellar Proper Motions.—In the *Astronomical Journal*, No. 979, W. J. Luyten gives a list of 441 stars with proper motions exceeding 0″·5 annually, in addition to revisions and corrections to his earlier catalogue of such stars published in the *Lick Observatory Bulletin*, No. 344. In the new list 208 have been

found by Ross and 105 by Luyten himself, while 38 stars given in the former list are now cancelled. In the two publications there are now available 1,153 stars with motions of 0″·5 or more, all components of visual binaries being counted separately. This number will be considerably increased when the systematic survey of the southern sky which is now in progress has been completed.

Minor Planets.—For many years Eros has held pride of place as being the planet making the closest approach to the earth. It is therefore remarkable that the year 1932 has seen the discovery of two new bodies which at certain times come well within the 13,800,000 miles which, even under the most favourable circumstances, divide us from Eros. Both these new planets were discovered by the aid of photography, for, as might be expected, they are very small, with diameters of the order of only two or three miles, and they are therefore difficult to observe except when they are near perihelion. The first discovery was made by Delporte at Uccle on March 12. Its minimum distance from the earth is only about 10,000,000 miles, its period is 2¾ years, and the eccentricity of its orbit is 0·45. On March 22 its distance from the earth was nearly minimum, so the discovery was made under very favourable conditions, and another close approach will be due in 1943. Delporte's planet held its record for only six weeks, for on April 27 Dr. Reinmuth at Königstuhl observed an object of the 12th magnitude with a retrograde motion in R.A. much larger than that of any known minor planet, and it was first assumed to be a comet. The orbit was calculated by Dr. Stracke, of the Berlin Rechen-Institut, and shown to be elliptical and highly eccentric, the period being 1·6 year (since altered to 1·8) and the eccentricity exceeding 0·5. Not only is this eccentricity the greatest known, but for the first time an asteroid has been found with an orbit actually coming inside those of the Earth and of Venus, the inclination to the ecliptic being about 6 degrees. It is possible for this body to approach the earth to within 2,000,000 miles, and such an approach should recur after periods of eleven years. Papers by Dr. A. C. Crommelin on these two asteroids are printed in the *Journal of the British Astronomical Assoc.*, May and June 1932. He mentions the possibility that Reinmuth's object may originally have been ejected from the earth when the latter's temperature was much higher than at present, while in Copenhagen *Circular No.* 365, V. Guth suggests that Delporte's planet may at some past epoch have split off from Eros, seeing that their orbits still approach to within 4,000,000 miles. A diagram showing the relation of the orbits of these two asteroids to those of Venus, the Earth and Mars is given by G. Stracke in *Astronomische*

Nachrichten, No. 5878. For about a century it was thought that the orbits of Mars and Jupiter marked the limits of the paths of the minor planets, but now those limits are pushed back to the orbits of Mercury and Saturn, and it is quite possible that these small bodies are distributed over the whole solar system. This makes it still more difficult to draw a rigid distinction between comets and asteroids. Orbits of large eccentricity and high inclination are no longer peculiar to the former, and the only real difference seems to lie in the development of a surrounding coma. It has not been possible to determine directly the mass of an asteroid with any certainty, and they have generally been regarded as solid and continuous, while in the case of comets the evidence is in favour of their being formed of matter loosely compacted. But the recent observations at Johannesburg, which showed a distinct elongation in the shapes of both Eros and Pallas, point to the fact that asteroids, as well as comets, are not solid and homogeneous bodies, but consist of aggregations of many pieces of matter. This naturally suggests a common origin for the two groups, the asteroids being possibly the final product of cometary disintegration. But as it is not yet known whether the comets were born within or without the Solar System the prime mystery of their origin and also of that of the asteroids still remains unsolved.

The Deflection of Light in the Sun's Gravitational Field.—In *Zeitschrift für Astrophysik*, Band 4, Heft 3 (1932), R. J. Trumpler criticises the Potsdam observations of the 1929 eclipse, from which a value of 2"·24 was obtained for the deflection of a ray of light grazing the sun's limb. This figure was considerably higher than any previously obtained, but it was claimed that a re-reduction of the Lick measures of 1922 raised the then adopted value of 1"·77 to 2"·2, thus securing a satisfactory agreement. Trumpler vigorously maintains the accuracy of the original figure, and considers that the higher value obtained by the Potsdam reduction is due entirely to an unsuitable choice of weights and an arbitrary exclusion of certain stars. In addition, he points out certain weak points in the Potsdam 1929 observations. The star field was very unsymmetrical, for out of the 18 stars bright enough to be photographed no less than 17 were located on one side of the sun. The reduction was based on the assumption that the light deflection was, in accordance with Einstein's theory, inversely proportional to each star's angular distance from the sun's centre, whereas in the final results the deflections were not so proportional. The method used for the scale determination is regarded as unsound. A collimating telescope was used to copy a réseau of fine lines on each of the eclipse and the comparison plates, and it was assumed, unwarrantably according to Trumpler, that the angle

corresponding to a réseau interval remained unchanged during the period of six months which elapsed between the two sets of observations. A new reduction of the measures in which a value for the scale correction is derived from the stars themselves, all the plate constants being redetermined with the scale value added as an extra unknown, gives the result $1''\cdot75 \pm 0''\cdot13$. This agrees almost exactly with Einstein's prediction, with the published results of 1922, and with the earlier observations of 1919.

Prof. Freundlich and the other Potsdam astronomers remain in direct disagreement with these conclusions, and reply to them in a paper which immediately follows. They maintain the accuracy of their measures, their method of reduction, and their system of weighting, and claim that by deriving the scale value independently of the star field itself a distinct advantage has been derived. Meanwhile, work is proceeding on the plates taken with the astrographic telescope at the same eclipse, and a further discussion is promised when this is completed and additional evidence thus becomes available. There is no doubt that the measurements are very near the limits of observational determination ; in the photographs made at each eclipse there have been anomalies in a certain number of stars, some showing too great a deflection, others too little, some being shifted nearly at right angles to the expected direction and others nearly opposite to it. Very different results can therefore be obtained by altering the methods of weighting, and it is clear that the observational data are not yet perfectly satisfactory. Further investigation is obviously necessary as occasion offers.

Royal Observatory, Greenwich.—In his report (June 1932) to the Board of Visitors the Astronomer Royal refers to his coming retirement under the Civil Service age limit, and reviews the work of the observatory during his twenty-two years tenure of office. During this period its activities have been continually extended to keep pace with the newer developments of astronomy, but this has not entailed any sacrifice of the fundamental observations for which it was originally founded. The determination of the positions of the sun, moon, planets, and brighter stars, the variation of latitude, the constants of aberration and nutation, and visual measures of double stars all figure prominently on the observing programme. But photography has been brought into much more general use, as in the determinations of stellar parallax, proper motions, standard magnitudes, effective wavelengths, and the absolute colour temperatures of stars. The ordinary solar photographs have been supplemented by daily observation, whenever possible, with the spectro-helioscope. The broadcasting of signals has been

added to the responsibilities of the time department, and its equipment has been greatly improved by the acquisition of three Shortt free pendulum clocks as standard time-keepers. The electrification of the Southern Railway suburban system necessitated a transference of the magnetic observatory to Leith Hill in Surrey, and the observing equipment is now of the most modern and efficient character. There is thus no branch of the observatory work which has not been maintained in a manner worthy of its traditions. The Astronomer Royal has the further satisfaction of seeing preparations well advanced for important additions to the instrumental equipment. A reversing transit circle of 7-inch aperture and 8 feet focal length, fitted with a motor-driven impersonal micrometer, is approaching completion, while through the generosity of Mr. Johnstone Yapp a 36-inch Reflecting telescope will shortly be mounted in a 34-foot dome erected on the site of the old magnetic observatory.

The regard in which Sir Frank Dyson is held in astronomical circles throughout the world was fittingly demonstrated by his election as President of the International Astronomical Union which met in September at Cambridge, Mass. His contributions to astronomy have been many and varied, but possibly the most spectacular was the organisation of the eclipse expeditions of May 1919, when Einstein's theory of relativity was first put to a practical test. It is, at any rate, typical of his vision, his enthusiasm, and his promptitude in action. Sir Frank will carry with him into his retirement the affectionate respect and cordial good wishes of the whole astronomical fraternity, and especially of those who have had at any time the privilege of working under his direction.

PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London.

German Contributions.—An interesting paper by E. Vogt, on the diamagnetism and paramagnetism in series of mixed crystals of metals, contains an examination of the corrections to be applied to the measurement of susceptibilities by the Gouy method when the materials under investigation contain traces of ferromagnetic impurities. The Gouy method is that in which a long uniform cylinder of the material is suspended from one arm of a sensitive balance, so that one end of the cylinder is in the uniform field of an electromagnet and the other in a region where the magnetic field is very small.

Although we have no exact knowledge of the way in which a ferromagnetic substance such as iron behaves when it is in the extreme dilution which obtains when it is present as an impurity, it is generally assumed that the Honda formula

holds, viz. $x_H = x_\infty + \sigma/H$, where x_H is the measured susceptibility when the field of the electromagnet is H, x_∞ is the true susceptibility of the material, and σ the intensity of magnetisation of the ferromagnetic impurity in unit mass of the material.

Now, it is clear from the experimental arrangements that the value of σ must vary from one end of the cylinder of material to the other. Consequently, Vogt shows that the measured susceptibility is more accurately represented by $x_H = x_\infty + 2\sigma'/H - 2D/H^2$, where σ' is the saturation value of the ferromagnetisation, and D is the area of that portion on the hysteresis diagram of the material, lying between the hysteresis curve, the axis of ordinates and the line $\sigma = \sigma'$—a portion which is practically a right-angled triangle.

The formula just given applies to the case where one end of the cylinder is in a zero field, and it must be slightly modified if this is not the case. Since H is usually several thousand gauss, the third term of the formula is usually negligibly small, and the Vogt and Honda formulæ therefore differ mainly by the 2 in the second term.

Vogt has examined the magnetic behaviour with atomic concentration of the mixed crystal alloys gold-silver, gold-copper, gold-palladium, and platinum-palladium at room temperatures. The diamagnetic series, gold-silver and gold-copper, show slight departures from the linear law of mixtures—the so-called Wiedemann rule, whilst the paramagnetic series gold-palladium and platinum-palladium show large departures.

It is suggested that the Pd^+ ions in the alloys take up electrons to form neutral Pd atoms which are diamagnetic. It is well known that by taking up hydrogen palladium becomes much less paramagnetic, and it is interesting that, concurrently with the increasing loss of paramagnetism with increase in concentration of the noble metal in the silver-palladium and gold-palladium mixed crystals, their powers of absorbing hydrogen are markedly decreased. Moreover, the slow change of susceptibility with time which occurs when a gold-palladium alloy is cooled to − 183° C. suggests a displacement of the equilibrium which may be assumed to exist between the number of Pd^+ ions and the number of neutral Pd atoms present in the alloy.

Two papers on the Wiedemann-Franz-Lorentz constant have recently appeared. This constant, often denoted by L, is defined as the ratio of the specific electrical conductivity of a metal to the product of its thermal conductivity and the absolute temperature at which these conductivities are determined.

In one of these papers, H. Reddemann (*Ann. der Phys.*, **14**, 139, 1932) describes experiments carried out with single

crystals of mercury. He finds that within the limits of experimental error the constant is the same along the several crystal axes at $-76°$ C. Since the individual determinations of the conductivities vary by 1 or 2 per cent., there remains, of course, the possibility that a small difference may exist between the value of the constant for the several axes. The mean value of the constant is $2{\cdot}55 \times 10^{-8}$ ohm. watt deg.$^{-2}$ at $-76°$ C., which is about the mean value found for other metals.

At $-187°$ C., however, there are definite differences between the values along the several axes, and the value of L parallel to the principal axis is about 4 per cent. greater than that of L perpendicular thereto. It appears that the latter value continues practically unchanged between $-76°$ and $-187°$ C., whilst the value parallel to the principal axis increases. Kamerlingh Onnes found with mercury (polycrystalline) a decrease in L at very low temperatures, as is to be expected from the behaviour of other metals, and the fact that the decrease occurs only at very low temperatures is in accord with the low value of the characteristic temperature of mercury.

Reddemann also finds that 23×10^{-7} and $27{\cdot}5 \times 10^{-7}$ volt. deg.$^{-1}$ represent the differences in thermoelectric power along the two principal axes in mercury at $-76°$ and $-187°$ C., respectively, when the single crystal forms a thermoelectric circuit with another metal, such as constantan. The sense of these differences is such that at the colder junction the current would flow from the principal axis to the axis perpendicular to it.

In the other paper, Goens and Grüneisen describe experiments on the electrical and thermal conductivities of single crystals of zinc and cadmium along the two principal directions in the crystals. Both metals exhibit a rapid rise in thermal conductivity at lower temperatures. It is found that the constant L, for directions parallel and perpendicular to the principal axis, is not very different from the average value for metals, at room temperatures, but it decreases with fall in temperature the more rapidly for that direction which possesses the higher characteristic temperature. This direction is perpendicular to the principal axis in both metals. The statement that the characteristic temperature is high for a given direction is, of course, equivalent to the statement that the velocity of sound is high in that direction.

In the case of metals which crystallise in the regular system the thermal conductivity is found to be the same for a single crystal as for a polycrystalline specimen. In the case of metals, such as antimony and bismuth, which crystallise in the non-cubic system, Eucken and his collaborators state that a single crystal specimen has a greater thermal conductivity than a polycrystalline specimen. Bidwell states that this holds for zinc.

It is supposed to be an effect due to the size of the particles under investigation. Goens and Grüneisen, however, consider that the presence of this effect is not established in the cases of zinc and cadmium.

The preliminary experiments described by W. Gerlach at the Physical Society's discussion on magnetism (*Proc. Phys. Soc.*, London, **42**, 418, 1930) have been elaborated by H. Broili (*Ann. der Phys.*, **14**, 259, 1932). The latter has examined the longitudinal difference of potential established along a wire of iron or nickel whose ends are at different temperatures, when a longitudinal magnetic field is applied to the wire.

For a given difference of temperature between the ends of a nickel wire, this difference of potential attains a maximum, constant value when the material is magnetically saturated. It also attains a constant value when the magnetisation and the lower temperature, T_1, are maintained constant, while the upper temperature, T_2, is above the (ferromagnetic) Curie point. When T_2 is above the Curie point, θ, the difference of potential is given by $E_m = c\,(\theta - T_1)^2$, where c is a constant.

A wire of pure electrolytic iron is peculiar in that for a constant temperature difference between the ends of the wire the difference of potential rises to a maximum, then decreases to zero, and finally increases to a constant value in the opposite sense, as the magnetising field is increased. If, however, the wire is " recrystallised " at 600° C., it then behaves in a similar manner to a nickel wire, except that the sense of the potential difference is reversed. If only one-half of the iron wire is " recrystallised," a considerable difference of potential is set up between the changed and the unchanged portions, even in the absence of a magnetic field.

The latter difference of potential shows a regular increase to a very sharp maximum somewhere in the neighbourhood of 850° C., and it appears to be connected in some way with the β, γ change. It is, however, very extraordinary that there seems to be no indication of any abrupt change at the ferromagnetic Curie point. The experiments are being continued.

Some time ago Wentzel (*Zeit. für Phys.*, **40**, 574, 1927) used the methods of wave mechanics to investigate the emission of electrons from the ground-levels of hydrogen-like atoms exposed to plane polarised ultra-violet light. He showed that the probability of the emission of a photo-electron is greatest along the direction of the electric vector in the incident light. The probability of the emission of a photo-electron in any other direction is equal to the product of the probability of emission along the electric vector, and the square of the cosine of the angle between the direction of emission and the electric vector.

These theoretical results have now been tested experi-

mentally by A. Kraus (*Ann. der Phys.*, **14**, 103, 1932). He illuminated a stream of potassium vapour by a beam of plane polarised ultra-violet light from a cold mercury arc. The beam of light was perpendicular to the stream, and the illumination took place within a small cylindrical enclosure provided with slits for the entry of light and vapour, and for the exit of photo-electrons. The vapour pressure was so low that collisions of the second kind did not enter into the experiments.

The photo-electrons emitted in a direction perpendicular to both light beam and vapour stream came under the influence of an accelerating field and passed through a series of slits into a Faraday cylinder. Consequently, by rotating the polariser, the angle between the electric vector and the direction of emission could be varied. The numbers of electrons collected by the cylinder for different positions of the polariser agreed with those expected from Wentzel's results.

As is well known, very short electromagnetic waves may be communicated to a Lecher wire system by coupling the two wires, through condensers, respectively to the grid and plate of a valve, a high positive potential being applied to the grid and a low negative potential to the plate. Although the effects of the presence of traces of gases in the valves used for the production of these short-wave oscillations have been examined, two questions appear to remain open. These are, namely, whether the presence of gas is necessary for the production of the oscillations, and whether the nature and pressure of the gases have any effects on the energy and the frequency range of the oscillations.

H. Rindfleisch (*Ann. der Phys.*, **14**, 273, 1932) has recently carried out quantitative measurements with tubes—including one used by Barkhausen and Kurz when they produced such oscillations for the first time—containing traces of helium and neon. He finds decisively that the presence of gas is not necessary for the production of oscillations. He also finds that in all cases the presence of the gas produces an increase in the wave-length of the oscillations, in addition to a decrease in their intensity. Consequently, if the Lecher wire circuit is set for resonance when no gas is in the tube, the increase of wave-length resulting on the admission of gas to the tube produces a further, indirect, reduction of the intensity of the oscillations—a reduction which has not been previously recorded. No reason for this reduction is given, but it seems to the writer that as the internal capacity of the valve plays a great part in the production of these oscillations, an ionised gas with its large dielectric constant should play an important part in settling the value of the internal capacity, and, hence, of the wave-length of the oscillations.

A promising new method for the measurement of the conductivity of a poorly conducting substance, which may only be obtained in the form of a powder, is described by A. Völkl (*Ann. der Phys.*, **14**, 193, 1932). Earlier methods of measurement depend on the compression of the substance into a tightly packed pastille, and are subject, obviously, to serious error. The new method may be used for electronic and electrolytic semi-conductors, but, provisionally, its use has been restricted to substances with conductivities between 10^{-4} and 3×10^{-8} ohm^{-1} $cm.^{-1}$.

It requires the provision of two identical condensers. One is filled with a mixture of the substance under investigation with a good insulator—usually white vaseline or powdered silica. The other is filled with the good insulator only. Each condenser is in turn placed in parallel with a standard condenser forming part of an oscillatory circuit, and two resonance curves are obtained. From these curves the difference in capacity of the condensers and the damping produced by the semi-conductor, with a known frequency, can be obtained. These quantities are found for a range of frequencies and for different temperatures. The value of the resonance capacity, multiplied by the damping, is plotted against the logarithm of the wave-length, for a given temperature, and from the position of the maximum the conductivity of the substance can be found at that temperature.

For the theory which forms the basis of the calculation the original paper must be consulted. The method has been well tested both by Völkl and by Guillery (*Ann. der Phys.*, **14**, 216, 1932).

BIOCHEMISTRY.

By W. O. Kermack, M.A., D.Sc., Royal College of Physicians, Edinburgh.

Nature of Flower Pigments.—The investigation of the pigments responsible for the enormous variety of tints which exist in flowers has for long presented very great difficulties, but progress has been rapid since Willstätter and his collaborators first succeeded in purifying and determining the constitution of the essential part of the colouring matter of the blue cornflower, cyanidin.

Of recent years this work has been rapidly extended, especially by Robinson and his collaborators. It has now been possible to make a wide survey of the distribution, in various plants, of different types of pigments, and the results, although of a preliminary nature, are of very great interest and importance. Robinson and Robinson (*Biochem. J.*, **25**, 1931, 1687) give a full account of the methods used and a detailed summary of the results obtained, while in *Nature* (**130**, 1932, 21) the same

authors outline the chief results and the general principles which emerge. The actual pigments which exist in the plants are glucosides, anthocyanins, compounds of glucose or some other sugar with an organic compound, an anthocyanidin; and it is this latter compound which is the seat of the colour. It is of very great interest to note in passing that Robinson and his collaborators have in recent years succeeded in synthesising not only a very large variety of anthocyanidins, but also a number of the complete glucosides, the anthocyanins, identical in all respects with the compounds as they exist in nature (see *Science Progress*, **27**, 1932, 27). A wide survey, covering many different orders of plants, brings out the fact that the anthocyanins which exist in nature are in almost every case derivatives of one of three compounds, pelargonidin, cyanidin or delphinidin. There are, however, some exceptions to this rule, *e.g.* gesnerin, a 5-saccharide of 4′ : 5 : 7 : trihydroxyflavylium chloride, but the exceptions appear to be relatively few.

Although it might appear that, by this limitation to three types of anthocyanidin, the variety of possible colours would be considerably limited, yet any possible disadvantage which the plant might suffer from this is amply compensated for by the use which it makes of co-pigments. The discovery that the colours of a solution produced by the anthocyanidin, pelargonidin, could be markedly modified by the presence of tannin was made by Willstätter and Zollinger (*Liebig's Ann.*, **412**, 1916, 195), but the importance of these co-pigments in nature has only recently been brought out by Robinson and Robinson in the two articles quoted above; for instance, it would seem that the pigment present in the violet corolla of the fuchsia is essentially the same as that present in the outer bluish-red petals, but that in the former case there is also present tannin which modifies the colour, making it more blue. In fact, it appears that varieties or closely related species although different in tint frequently have exactly the same pigment within their petals, and that the different colours are produced by variation in the amount or nature of the co-pigment, or by combination of both. Thus in ordinary lilac a co-pigment, which exists in the white flowers, produces the pale mauve colour in presence of a small amount of pigment, tending to deeper red as the amount of colouring matter is increased, whilst for the deeper bluer-red tints increase or modification of co-pigment as well as pigment would seem to be required.

It would appear that when closely related species or varieties are under consideration the variation in pH is not responsible for the change in colour, although this may play a part when quite different species are concerned. Thus it was shown by Willstätter and Everest (*Liebig's Ann.*, **401**, 1913, 189) that the

pigments present in the blue cornflower and the rose and dahlia are probably identical, the former existing, however, as the blue potassium salt and the latter two as the oxonium salt of an organic acid. These results are obviously of great importance in the consideration of the problem of the origin and function of the plant pigments and also of their bearing on the phylogenetic relations between different varieties and different species. Apart from the actual results obtained, a very important advance is the development of methods for analysing the pigments when only a small amount of material is available, and with an amount of labour small enough to make a survey of a very large number of different plants a reasonable undertaking.

Proteins.—During recent years Svedberg and his collaborators in a series of papers in the *Journal of the American Chemical Society* (see also *Koll. Zeit.*, **51**, 1930, 10) developed a method for the investigation of the size and shape of protein particles in solution, which is of very great interest and importance. The principle involved is a very simple one. The rate of sedimentation of a particle in a viscous fluid depends on its shape and size, so that observations on the sedimentation give information on its shape and size provided that the viscosity of the fluid and the density of the fluid and the particle are known. When an attempt is made to apply this method to the particles present in a protein solution, which are very small, it is necessary to work with a centrifugal field equal to very many times the ordinary gravitational force. To produce centrifugal fields of sufficient intensity Svedberg has designed the " Ultracentrifuge " which enables fields up to 100,000–200,000 times the gravitational field to be produced It is not possible to describe here the technical details of this remarkable machine. It must suffice to give a brief account of some of the more interesting conclusions, especially those of biological significance. It may first of all be remarked that Svedberg usually refers to the weight of the protein particles as their " molecular weight," but it seems clear that what is really determined is the weight of the separate particles or micelles which might be made up of a number of molecules. As, however, the words " molecular weight " are convenient and are customarily used in the description of Svedberg's results, they will be frequently employed below, but the above reservation should always be kept in mind.

It has been found that proteins may be divided into two classes. Those in the first class, which includes gelatin, casein, lactalbumin, histone, muscle globulin and euglobulin, exist in solution in the form of particles of various sizes, *i.e.* they are polydisperse. In the case of the proteins which belong to the second class the individual particles are, within experimental error, of exactly the same size.

Protein.	Molecular weight.
Ovalbumin, Bence Jones protein	34,500
Hæmoglobin, Serum albumin	68,000 (2 × 34,500 approx.)
Serum globulin	103,800 (3 × 34,500 approx.)
Amandin, Edestin, Excelsin, Legumin, *C*-Phycocyan, *R*-Phycocyan, *R*-Phycoerythrin	208,000 (6 × 34,500 approx.)
L-Hæmocyanin	2,000,000
H-Hæmocyanin	5,000,000

It will be seen from the table that proteins of this homogeneous type apparently belong to one of two groups, (i) those of relatively low molecular weight, 34,000–200,000, and (ii) those of very high molecular weight of the order of millions as exemplified by the hæmocyanins. It is very curious to find that the proteins in group (i) appear to divide into four sub-groups: those with molecular weights 34,500; 2 × 34,500; 3 × 34,500; and 6 × 34,500 respectively. Some kind of building-up process from a unit of 34,500 seems to be indicated. This conclusion is forcibly emphasised by two very interesting observations. The first is that the protein micelles in the first and fourth sub-groups are, according to Svedberg's observations, approximately spherical; whilst those in the second and third sub-groups are definitely non-spherical. This is just what one would expect if the 34,500 units were approximately spherical in shape and the micelles in the 2nd, 3rd, and 4th groups were formed from two, three, and six of these units. Secondly, the proteins, *e.g.* in the fourth sub-group, in solution in alkali of sufficient strength undergo disaggregation into smaller particles of weight 104,000, 68,000, and ultimately 34,500. This disaggregation takes place without change in the isoelectric point.

In a more recent article (*Nature*, **128**, 1931, 999) Svedberg has described some unexpected results which he found when attempting to determine the molecular weight of lactalbumin. In the earlier work the proteins were purified by fractionation and crystallisation in presence of ammonium sulphate. It was found, however, that when this method of purification was applied to lactalbumin the apparent molecular weight of the protein progressively increased during the process. Before treatment the crude lactalbumin had a molecular weight of about 1,000 and after some purification it rose to 12,000–25,000. This at once opened the whole question as to whether the results given above can be in any way taken as representing the molecular weights of the proteins as they exist in nature. Repetition of the observations, using simple extracts in dilute aqueous sodium

chloride solution, gave results substantially in agreement with those previously obtained. From this it is to be inferred that the proteins exist in their natural state with the molecular weights as given above. The one exception so far met with apart from lactalbumin is ovalbumin; as shown in the table purified crystalline ovalbumin has a molecular weight of 34,500; when prepared simply by diluting the white of hen's egg with 1 per cent. sodium chloride solution much lower but variable values were obtained. It is of some interest to note that in the case of preserved eggs values were always found agreeing with those for pure crystalline ovalbumin. It thus seems that ovalbumin may sometimes exist in the hen's egg in a form with an abnormally low molecular weight which readily changes into the ordinary crystalline variety. Although the general results confirm the validity of the original determinations of the molecular weight, nevertheless the observation that in some cases the protein can exist in the form of unstable pro-protein units of relatively low molecular weight may prove when followed up to be of very considerable importance.

As shown in the table, hæmocyanin is an example of a protein belonging to the second group, its molecular weight being of the order of several millions. As is well known, hæmocyanin is a respiratory pigment found in certain invertebrates where it plays the part taken by hæmoglobin in the vertebrates. It differs, however, from hæmoglobin in two important respects, that it contains copper instead of iron and that it does not exist in corpuscles, but in free solution in the blood plasma. It is known, however, that in certain species of lower animals respiratory pigments exist in free solution and not in corpuscles which resemble hæmoglobin in containing iron. J. and H. Barcroft (*Proc. Roy. Soc., B.*, **96**, 1924, 28) have shown that the iron-containing pigment in *Arenicola* closely resembles hæmoglobin spectrographically and also in respect of its oxygen and carbon monoxide affinities. Svedberg (*Nature*, **130**, 1932, 434) has published observations made on respiratory pigments of this type. The pigment of *Arenicola* was found to have a sedimentation constant of 60×10^{-13}, indicating a molecular weight of several millions. Chlorocruorin, the respiratory pigment from *Spirographis* which also contains iron and fairly closely resembles hæmoglobin, is also found to have a molecular weight of greater than 1,000,000, whilst the pigment in *Lumbricus* has a sedimentation constant of 68×10^{-13}, thus also having a molecular weight of several millions.

It would thus seem as if the extra-corpuscular respiratory pigments of invertebrates are characterised by their high molecular weight in solution; and as Svedberg remarks, it will be a matter of considerable interest from the biological point

of view to find out at what point in the process of evolution respiratory pigments having smaller molecular weights such as hæmoglobin first came into existence.

The ultracentrifuge, like most novel instruments of research, has enabled new ground to be opened up in more directions than one. Valuable information has been gained as to the stability of proteins under different conditions of acidity and alkalinity, but space does not suffice to discuss these points at greater length. It is of great interest to note that the molecular weight of crystalline insulin has been determined by means of the ultracentrifuge. It is found to be about 34,500, and Svedberg draws the conclusion that insulin belongs to the ovalbumin sub-group of proteins.

Reversal of Protein Coagulation.—Whilst dealing with recent work on the chemistry of proteins attention may be directed to an interesting series of papers by Anson and Mirsky on denaturation. It is now a considerable number of years since Chick and Martin (*J. Physiol.*, **40**, 1910, 404; **43**, 1911, 1) found that the coagulation of a native protein, *e.g.* ovalbumin; could be regarded as taking place in two stages. The primary effect, produced by the coagulating agent, heat, acid, alcohol, etc., consists in altering the protein from the original soluble form to a form no longer soluble at its isoelectric point, but usually soluble in the presence of sufficient acid or base; in other words, a change from a hydrophilic to a hydrophobic colloid. The second stage consists in the precipitation of this insoluble form at its isoelectric point or by means of salts. Until recently it had usually been considered that the first stage, commonly called denaturation, was characterised by complete irreversibility.

Some years ago Spiegel Adolph (*Biochem. Zeit.*, **170**, 1926, 126) brought some evidence to show that a certain degree of reversibility might sometimes be obtained. More recently Anson and Mirsky (*J. Gen. Physiol.*, **13**, 1929, 121, 133, 469, 477) have published details of experiments with hæmoglobin which appear to demonstrate the reversibility of the process of denaturation in a simple and at the same time striking manner. For example, a solution of hæmoglobin prepared by taking ox-red blood cells is made acid by the addition of N/5 HCl and then kept at 80° C. for three minutes. Complete denaturation apparently takes place as the protein is completely precipitated when the solution is brought to the isoelectric point. If, however, the cooled solution is made slightly alkaline and sodium hydrosulphite added to bring the hæmoglobin to the reduced form, a reddish colour slowly develops in which after some shaking the characteristic spectrum of hæmoglobin may be detected. The reversal proceeds more

efficiently in the presence of sodium cyanide, the first product to be formed in this case being cyanmethæmoglobin. Anson and Mirsky have shown that from hæmoglobin apparently completely denatured a crystalline product in the form of carboxyhæmoglobin, and ultimately crystalline oxyhæmoglobin may be obtained in a yield of 70 per cent. of the original. It was shown in 1927 by Hill and Holden (*Biochem. J.*, **21**, 1927, 625) that apparently undenatured globin could be combined with hæm, the prosthetic group of the hæmoglobin molecule, to yield hæmoglobin indistinguishable from fresh hæmoglobin; but that denatured globin, though it did combine with hæm, yielded a hæmochromogen quite different from hæmoglobin. Anson and Mirsky have been able to show that the process of reversal of denaturation may be applied to the denatured globin and that hæmoglobin may be resynthesised from the product of reversal. In fact, they state reasons for believing that Hill and Holden even with their precautions were unable to prevent the denaturation of the relatively unstable globin in the process of producing it from hæmoglobin, and that these workers really by their experimental conditions reversed this denatured globin to native globin which then combined with hæm. The idea that denaturation is reversible is so unorthodox that it is not surprising that although the experimental facts recorded by Anson and Mirsky are admitted the interpretation is questioned (Wu and Lin, *Chinese J. Physiol.*, **1**, 1927, 219 and 431); nevertheless, the various lines of argument which they have advanced on the basis of a large number of experimental results have, taken together, very considerable weight. Their conclusions are strengthened by the fact that they have been able to extend their methods to at least one other protein, having been able to reverse the denaturation of serum albumin (*J. Gen. Physiol.*, **14**, 1931, 725) and to crystallise the product obtained. This result is in harmony with the earlier work of Spiegel Adolph mentioned above. Their own conclusion seems certainly to be justified, namely, that "protein coagulation in general is probably reversible." Further work on similar lines, especially with other proteins, will be awaited with interest.

Cause of Exophthalmic Goitre.—During recent years much progress has been made in the elucidation of the problems connected with the physiology and pathology of the thyroid gland. The remarkable work of Harington and Barger (*Biochem. J.*, **21**, 1927, 169) on the separation, constitution, and synthesis of thyroxine (see *Science Progress*, **24**, 1929, 15) is now well known, and this has been more recently followed up by further papers by Harington and his collaborators, the chief results of which are to show that thyroxine exists in the gland

in combination with protein in the form of its *l*-optical stereoisomer (*Biochem. J.*, **24**, 1930, 456), and that apart from thyroxine itself probably the only other organic constituent of the thyroid gland containing iodine is *d*-3 : 5-diiodotyrosine (*Biochem. J.*, **25**, 1931, 1032). In spite, however, of these important advances the problem of the etiology of exophthalmic goitre in the human subject has remained unsettled. It has been clear for some time that the mere excess production of thyroxine by the hypertrophied thyroid is by no means sufficient to explain all the facts. In particular, administration of thyroxine does not of itself produce the characteristic protrusion of the eyes (exophthalmos) nor the various toxic symptoms associated with the condition, whilst the remarkable beneficial though temporary effect of the administration of iodides is not related in any obvious way to a simple hyperactivity of the thyroid gland. Very interesting light has been shed on this problem by recent work by Loeb and others in which a causal relation to the anterior lobe of the pituitary is suggested. It has been found by Loeb and Friedman (*Proc. Soc. exp. Biol. and Med.*, **29**, 1932, 648) that acid and alkaline extracts of the anterior lobe of the pituitary when injected into guinea pigs produce a picture showing many of the features characteristic of exophthalmic goitre in the human subject. There is, for instance, a rise in the basal metabolism, accompanied by general emaciation, curious characteristic changes in the histology of the thyroid gland associated with hypertrophy of the latter. Furthermore these effects of anterior lobe extracts are said to be inhibited by the administration of iodine, corresponding to the beneficial effect of these salts in exophthalmic goitre. Obviously, accurate objective evidence of the development of the bulging of the eyes characteristic of exophthalmic goitre is somewhat difficult to obtain, but Loeb now claims that by careful experimentation he is able to prove that this symptom also accompanies the administration of his anterior lobe extracts. This observation would seem to add very considerable weight to his views as to the ætiology of exophthalmic goitre and its relation to the pituitary. It may also be added that Schockaert (*Amer. J. Anatomy*, **49**, 1932, 379), working with ducks, has obtained results which in general also demonstrate the effect of the anterior lobe of the pituitary on the thyroid gland. According to this author the marked changes which occur in the thyroid after administration of the anterior lobe extracts seem to be associated with the mobilisation and secretion of its active constituents, and is accompanied by a very marked fall in the iodine content of the thyroid. It is now well known that the anterior lobe of the pituitary contains a growth-promoting hormone and one or more hormones which

act on the ovary and are intimately related to sexual function. Loeb (*Proc. Soc. Exp. Biol. and Med.*, **29**, 1932, 642) has examined the action on the thyroid of extracts made from the anterior lobe of the pituitary of ox, rabbit, etc., and he finds that the action on the ovary runs roughly parallel with the action on the thyroid. However, extracts made from the urine of pregnant women show very marked ovarian action, but are without effect on the thyroid. We cannot at present conclude that the material acting on the thyroid is identical with any of the sex hormones. In addition to the practical importance of this work it is of considerable interest as emphasising once more the intimate relations which exist in the body between the various organs of internal secretion.

PHYSICAL CHEMISTRY. By O. H. WANSBROUGH-JONES, M.A., Ph.D., Laboratory of Colloid Science, Cambridge.

WHILE it is no new thing for the physical chemist to interest himself in protein structure, and its relation to the chemical and biological behaviour of the proteins, the results so obtained have not often in the past been either satisfactory or susceptible to direct interpretation in terms of the structure and function of living material. A three-sided attack in the past year or so is now becoming so formidable that it seems apposite to give some account of the methods used and of the results obtained. The three lines of attack are briefly these : X-ray analysis by means of which the structure of the protein chain and the spatial relation of these chains to each other may be examined ; methods which attempt rather to assign position to the side chains and in particular to their power of hydration, ionisation, etc. ; and methods in which a single layer of protein molecules is examined, either by means of force-area curves, surface potentials, or the chemical and biochemical reaction of such films. Naturally enough, all these methods must be considered together.

The methods of X-ray analysis have been most exactly applied to biologically inactive material such as hair, silk, etc., and in most cases these are definitely but imperfectly crystalline, built up of long and narrow crystalline particles with axes parallel and with a definite orientation to the axis of the fibre. In the case of silk fibroin, it was fairly clear that the diffraction pattern obtained was due to bundles of long polypeptide chains, but other substances of like character, such as hair, muscle, collagen and so on, were less satisfactory. Fortunately, Astbury (Astbury and Street, *Phil. Trans. Roy. Soc.*, A., **75**, 230, 1931) discovered that the pattern due to hair keratin underwent a profound change when the fibre was stretched, changing from a pattern quite unlike that of silk

when in the normal condition, to a pattern analogous to that of silk, and therefore of long bundles of polypeptide chains, when extended. It is thus suggested that the polypeptide chains which exist normally in some folded state in the keratin molecule may be pulled out into an extended state resembling that of the fibroin molecule (Astbury, *Trans. Far. Soc.*, 28, 1932). A most convincing demonstration of this idea has very recently been given by Astbury and Marwick (*Nature*, **130**, 309, 1932). They photographed the X-ray diffraction pattern of feather keratin, obtaining for a normal quill of feathers a pattern seemingly quite unlike that of hair or wool, but which proved to be an elaboration of a form of these, and to arise from a chain of at least eight amino-acid residues in a contracted state. The application of a strong stretching force pulls the molecules more nearly into the more familiar silk form, or the stretched hair (β-keratin) form ; the respective periods corresponding to the lengths of single amino-acid residues being 3·5 Å. for silk ; 3·4 Å. for β-keratin, and 3·3 Å. for the stretched feather keratin. It seems safe to take it that these figures represent the configuration of the backbone of protein molecules, but their behaviour is obviously more influenced by the side chains branching out from the polypeptide backbone, and here the fibroin structure is a very unsafe guide because the side chains in this molecule, consisting merely of hydrogen and methyl groups, are as inactive as possible. Rather should we consider the more interesting, if more complicated, cases in which the side chains contain reactive groups. The evidence from X-ray photographs suggests that in many various proteins there is a regular distance of the order of 4½ to 5 Å. between parallel long chains, and attempts are made to interpret this distance in terms of the known distance of closest approach of the atoms linking the two chains together. Astbury gives 4·65 Å. as the distance between the axes of two protein molecules which are linked by alternate : CO and : NH groups in the respective backbones. It is then eminently reasonable to suggest that in one side dimension the chains are so linked together. The other side dimension must be that containing the side chains, and thus no such uniformity is to be expected. The facts are that a value between 9 and 10 Å. is commonly found, but this distance may be an average value due to the flexibility of the side chains, or it may be a value to be ascribed to a definite linkage between adjacent chains. It is too early to try to identify this value with the conventional inter-atomic distances except for a very few cases ; but Astbury makes one important point : that " any distortion of the main chain, due to interaction of the side chains, must lead to contraction " ; a necessary premise, moreover, to account for the small differ-

ences in the spacing of the links in the fibroin, β-keratin, and feather backbones. Before passing on to a discussion of the recent work on the activity of the side chains, two other points must be mentioned ; the first that in any protein aggregate, only a few of the protein molecules are arranged in a regular way, and further, that we must be reluctant to assign any great rigidity to the protein molecule either as a whole or to its side chains, and that in spite of the constancy of some of its dimensions, a free rotation of the constituent groups must be permissible.

One of the common properties of these fibroid and other proteins is their power of taking up water and swelling, with a corresponding change in physical and, as we shall see, chemical properties. The change in the X-ray diagram of stretched hair is, for example, only fully reversible when the hair is wet. We have seen also that the structure of these bodies is probably a large number of aggregates, " micelles," in which the molecules are arranged at a regular spacing described above. It is of interest to decide whether the water that is taken up goes into the intra-micellar spaces or into or between the molecules themselves, and a direct answer to this question is given by an examination of the X-ray diagram for the proteins in the two conditions. Katz (*Trans. Far. Soc.*, 28, 1932) finds that in the cases of gelatin and collagen the diagram undergoes a great change in the swelling process ; and further, the new interatomic distances are increased to a size large enough to account for the whole change in the dimensions of the swelling body. The process is very analogous to the formation of a solid solution of the water in the solid, but the water is presumably fairly firmly attached to the protein molecules, though it does not necessarily form a definite chemical compound with them. Another aspect of the rôle of water in combination with the protein is considered by Jordan Lloyd (*Biological Reviews*, 7, 28, 254, 1932) and Jordan Lloyd and Phillips (*Trans. Far. Soc.*, 1932). The amount of water taken up by a protein will depend on the number and character of the side groups and on the possibility of water being joined by a co-ordinate link to part of the peptide chain. This latter can occur readily on to the imino or ketone groups when these are in the uncharged condition, or also when ionised, and the amount of water taken up by a unit of the axis of polypeptide chains may be the same for all proteins, depending on the accessibility of these chains to the water. In general, it is slight, and the hydration of the protein as a whole depends most on the side groups. The influence of the presence of salts on hydration is also discussed, and further the structure of the protein molecule will also be important, the hydration being dependent on the length and

bulk of the side chains and on the closeness of packing of the molecules. Thus silk fibroin, and hair, which have very short, normally aliphatic side groups and which, therefore, approach close to each other and form a compact structure, are essentially dry, and the reverse is true of collagen where the side groups are larger and more complex. Should the arrangement of the molecules be highly organised there is less room for water molecules than when they are distributed at random; and further, at the iso-electric point when each molecule contains a large number of anions and cations as zwitterions the adjacent protein molecules will be drawn nearer together, causing a further drop in the amount of co-ordinated water. The varying amounts of water which are taken up by the different side chains is discussed in detail in these papers, and the changes in hydration with the *p*H are also followed. The amount of water present with a protein is biologically very important, since there is a marked parallelism between the biological activity of a protein in a cell, and the amount of water it contains. Thus wool and hair, which, as we have seen, are highly organised proteins of a very definite structure which precludes any large amount of water being present, are biologically inert, but on the other hand, the amount of water present in developing embryos is very large and roughly follows the curve showing their activity. Or correspondingly with a sample of gelatin in the form of a jelly, it has been found that water passes in and out of the jelly, *i.e.* swelling occurs, with the greatest ease when the gelatin concentration at the time of setting was low. Weak jellies when immersed in water will give up water, that is to say, the molecules of the protein will become more organised, leaving less space for water molecules between them.

So far, attention has only been paid to the properties of the protein molecule as a whole; but in many ways the surface properties are at least as revealing. The general relation between the electro-cataphoretic mobility of small particles to the potential and surface ionisation and adsorption of ions has long been known, but some points of detail have recently been cleared up and should be considered. The most usual method of determining the ζ-potential of a protein has been to determine the velocity of migration of protein-covered quartz particles in solutions of known *p*H under an electrical field, and then to use the Smoluchowski equation to determine the electro-kinetic potential. Debye and Hückel (*Phys. Z.*, **25**, 49, 1924), however, gave a different equation in which it seemed that the constant relating the mobility to the viscosity, field strength, dielectric constant, and electro-kinetic potential was dependent upon the shape of the particle, obviously a matter of extreme inconvenience when dealing with microscopic quartz particles. This

view was, however, at variance with most of the experimental facts, and the theory of Henry (*Proc. Roy. Soc.*, A., **133**, 106, 1931) gave a different theoretical treatment, and showed experimentally (Henry and Sumner, *Proc. Roy. Soc.* A., **133**, 130, 1931) that the effect on a large glass cylinder coated with protein of an electric field was the same whether the field was applied axially or broadside on. Abramson (*J. Phys. Chem.*, **35**, 289, 1931) has confirmed and extended this by showing that the ratio of the electrophoretic mobility of particles of various shapes and sizes coated with protein to the electro-osmotic velocity over a flat surface coated with the same protein was constantly − 1. The apparent changes due to variation in the effective radii of curvature are also discussed. Further experiments (Abramson, *J. Gen. Phys.*, **11**, 1, 1931) with highly purified protein confirmed this result.

The method of measurement of the mobilities of quartz particles covered with protein might not give the same mobility for these particles as for the dissolved protein which is of primary interest. This question has been examined by Abramson (*J. Gen. Phys.*, **15**, 375, 1932), and for egg albumen at least the mobilities and iso-electric points are apparently identical. This raises an interesting point as to the mechanism of the adsorption of the protein, since clearly practically all the polar groups of the protein molecule are available even after the adsorption has occurred. Abramson puts the limit of this loss of polar groups as a maximum loss of one available H^+ ion. Thus the mechanism of adsorption in no way changes the properties of the reactive groups, and the mass law in the bulk phase and at the interface are identical, and observations made on adsorbed protein in this way may be expected to be directly applicable to the biologically more interesting dissolved protein.

None the less, it must be remembered that some caution is necessary before any very definite structure can be assigned to the electrical layer. It is fairly certain that outside a rigid layer there is a more or less diffuse layer extending for some distance into the liquid, containing charged particles whose position may even be affected by mechanical means, and while this layer only contributes a small fraction of the total electrokinetic potential, our knowledge of its magnitude, stability and even sign, is as yet very imperfect.

In this connection two more sets of observations similar to Abramson's may be quoted. Prideaux and Howitt (*Proc. Roy. Soc.*, A., **126**, 126, 1930) have carried out an extensive series of observations on the mobilities of proteins adsorbed on gold sols and have found, like Abramson, little or no variation in the isoelectric point with the nature of the adsorbing material.

On the other hand, Dr. Bowden and Mr. Dummett (unpublished) have found that while the iso-electric point of gelatine seems independent of the underlying material, this is by no means true of all proteins, oxyhæmoglobin, for example, having an iso-electric point and so a cataphoretic mobility which seems to vary very markedly with the nature of the adsorbing material. For this effect they believe two causes are responsible, the first being that the surface is not completely saturated with the protein so the mobility observed is the sum of that due to the protein and the underlying material, while the second is that there is a real change in the iso-electric point due to adsorption, when the protein is attached to the carrier by some of the ionising groups. The two effects are distinguishable by increasing the concentration of the protein solution until it has no longer any effect on the mobility, at which point it is fair to assume that the surface of the carrier is completely covered. The curve relating the concentration of the protein to the mobility is an adsorption isotherm of the type showing a saturation maximum.

For the examination of unimolecular films of protein, two methods are available, either the study of the force-area curve in the Langmuir trough, a method made familiar largely by the work of Adam, and the method elaborated by Schulman and Rideal (*Proc. Roy. Soc.*, A., **130**, 259, 1931) in which the changes in the summed air-film-underlying liquid potentials are measured, and hence any change in configuration causing alteration in the vertical component of the electric moment of the molecule in the surface can be observed. A comparison between the cataphoretic experiments and such experiments as these has been made by Hughes and Schulman for the case of fatty acids spread over solutions of varying *p*H. It is clear from their experiments that the two methods are giving essentially similar results. Thus G. Koehler (*Z. Phys. Chem.*, A., **134**, 157, 1931) has found that most fatty acids display no electrosmotic mobility over the *p*H range from 2–4; and Schulman and Hughes find that while the absolute value of the surface potential in this range varies, the electric moments of the molecules as calculated from the Helmholtz equation remains unaltered. But transferring the film to strong acids, or alkalis where soap formation may occur, gives a very large change in the value of the electric moment, in accordance with the changed configuration of the molecules at the surface.

While for these purposes the surface potential method was in the main supplying corroborative evidence, when applied to protein monolayers it has given new and valuable results. The two methods of the force-area curves and the surface potentials should, however, be taken together. That proteins

could be spread over a surface had long been known (cf. Hercik, *Kolloid Zeit.*, **56**, 2, 1931; Metcalf, *Z. Phys. Chem.*, **52**, 1, 1905), and these and other workers computed the thickness of representative protein films (albumen, casein, etc.) spread by various methods as of the order of 40 Å. Other workers have also obtained erratic results and films whose thicknesses seemed to vary more than was reasonable, and Zocher and Stiebel (*Z. Phys. Chem.*, **147**, 401, 1930) found when such films were examined ultra-microscopically that they were far from homogeneous.

In order to obtain homogeneous films, Hughes and Rideal (*Proc. Roy. Soc.*, A., **137**, 62, 1932) adopted the method of spreading the films directly from minute particles of the protein held on a fine quartz fibre which acted as a microbalance of high sensitivity. Thus the protein particle was weighed directly before and after the film had spread from it. This method gave eminently satisfactory films, whose characteristics are reproducible, which seem to satisfy every test for homogeneity which can be devised, and which are quite unlike normal fatty acid films. As they begin to spread, they are definitely fluid, but as more protein comes on to the surface the films become solid but are remarkably elastic, and in fact appear to be gelatinous, and to supply the two-dimensional analogy to the three-dimensional gel such as may, for example, be made from gelatin and water. There is no sharp boundary between the initial liquid and the gelatinous film for the various proteins examined (gliadin, egg albumen, and glutenin). The spreading pressure at which the film becomes gelatinous is about 15 dynes per cm. for gliadin spread on dilute hydrochloric acid, and rather lower on alkaline substrates. The force-area curve is reversible while the film is in the liquid state, but this is not the case when the film has become a gel. The change in surface potential follows a similar course but shows a large increase as gelation occurs.

The interpretation of these results must clearly be made through the knowledge of the structure of the proteins which has been obtained by the X-ray measurements. The film thickness as determined by Hughes and Rideal is about 3 Å for the fully extended state (in which state the surface potential is small), and this probably corresponds to the position in which all the protein molecule, together with its side-chains, is lying flat in the surface, a picture to which the magnitude of the surface potential lends support. The next change in the film state is that due to compressing the molecules until the side-chains have closed in laterally as far as possible, and this also is supported by both sets of measurements. Further compression, which causes the transition to the gel state, must involve a

radical rearrangement, most probably the expulsion of the side-chains from the liquid surface, which would of course involve an increase in the film thickness to a length corresponding to that of the side-chains. Such a thickness of about 11 to 12 Å is actually found. The mutual attraction of the adjacent polypeptide chains might well be expected to give a much more rigid structure to the film, and this also is observed in the transition to the gel state. Finally, the polypeptide chains should approach to the distance of 4 to 5 Å and this figure is in agreement with the observations. Thus it may be claimed that the X-ray data and the results obtained from the direct examination of protein monolayers are mutually consistent.

GEOLOGY. By Prof. G. W. Tyrrell, A.R.C.Sc., D.Sc., University, Glasgow.

Petrography. Igneous Rocks.—The lavas of Tweeddale, near Peebles, which were formerly regarded as of Upper Caradocian age have now been demonstrated to be Lower Caradocian by R. J. A. Eckford and M. Ritchie (*Summ. Prog. Geol. Surv. for* 1930, pt. 3, 1931, pp. 46–57). Petrographical notes by D. Balsillie show that the lavas are keratophyres, and possibly represent a late soda-rich fraction of the Arenig spilitic magma of the same province.

D. Balsillie's paper on " The Ballantrae Igneous Complex, South Ayrshire " (*Geol. Mag.*, LXX, 1932, pp. 107–31), describes in modern terms a series of igneous rocks which have lately been neglected although of surpassing interest. Balsillie describes the spilite and " diabase-porphyrite " lavas of Arenig age, the serpentines and associated ultrabasic rocks, gabbros, albitites, foliated gabbros and granulites, granites, and dike-rocks. The chief petrographic points which are elucidated refer to the thoroughly sodic composition of the pole towards which the Ballantrae series differentiated, and the widespread albitisation which the rocks have suffered. The paper is illustrated by a number of new chemical analyses by B. E. Dixon of the Geological Survey.

The Saline No. 1 teschenite sill, 62 ft. thick, occurs in a boring through the Limestone Coals at Saline (Fife) at a depth of 2,166 ft. Near the centre of the sill occurs 20 ft. of soft rotten rock which proved to be olivine-rich teschenite (picro-teschenite). According to Sir J. S. Flett (*Summ. Prog. Geol. Surv. for* 1930, pt. 2, 1931, pp. 44–51), the concentration of olivine may have taken place in an intermediate magma chamber, or more probably, by a kind of elutriation process causing the gradual concentration of olivine crystals as the magmatic current ascended.

The Blackness teschenite sill near Bo'ness was penetrated by a boring and found to be 164 ft. thick. Its variations are

fully described by Sir J. S. Flett (*Summ. Prog. Geol. Surv. for* 1930, pt. 3, 1931, pp. 39–45). The sequence was " white trap " (upper contact) 2 ft., teschenite 8 ft., picrite 4 ft., teschenite 49 ft., picrite 78 ft., picroteschenite 19 ft., " white trap " (lower contact) 3 ft. The author draws the conclusion that the magma was heterogeneous on emplacement, having been differentiated either before or during its ascent. There appears to have been no significant amount of subsidence of olivine crystals, and when the intrusion ceased the mass was in such a viscous condition that even large masses of picrite remained suspended, and failed to sink through the underlying teschenite.

The Geological Survey Memoir on " The Geology of Ardnamurchan, North-west Mull, and Coll." (*Mem. Geol. Surv., Scotland*, 1930, 393 pp.), contains a rich store of valuable petrographical data as well as new conceptions of the geology and morphology of igneus intrusions (see SCIENCE PROGRESS, July 1932, p. 54). The major intrusions of the Ardnamurchan volcanic centres are mostly gabbro and quartz-gabbro with subordinate masses of granophyre. Eucrite, however, is met with, and there is also an important development of tonalite and quartz-monzonite which is practically unrepresented in the other Kainozoic centres of the west of Scotland. The authors (J. E. Richey and H. H. Thomas) assume that the " Plateau Basalt Magma " is the parent stock, and that the " Normal Mull Magma " is derivable from this by the initial abstraction of iron ores, olivine, and basic plagioclase, followed by partial abstraction of later crystalline phases such as augite and less basic plagioclase.

Dr. W. Q. Kennedy, however, is of the opinion that the " Non-porphyritic Central Basalt Magma " of Mull more nearly represents the parental magma than the " Hebridean Plateau Basalt " type (*Summ. Prog. Geol. Surv. for* 1930, pt. 2, 1931, pp. 61–73). He shows that the Mull magma agrees extremely well with the average plateau basalt of the world, whilst the Hebridean Basalt magma differs markedly from both in several chemical and mineral characters. His view of the general course of differentiation in the basaltic magma of the Hebridean province is :

Non-porphyritic Central Magma

Non-porphyritic Central Magma	Plateau Magma
(acid var.)	(olivine-rich)
Inninmorite	Mugearite
Granophyre	Syenite (or Trachyte)

Dr. F. Walker, writing on " Differentiation in the Sills of Northern Trotternish (Skye) " (*Trans. Roy. Soc., Edin.*, LVII,

pt. 1, 1932, pp. 241–57), finds that olivine-dolerite is the most abundant rock type in these igneous bodies, but that there is a great development of picrite in the thicker masses, and that teschenite and dolerite-pegmatite are also present. Differentiation by the gravitational settling of olivine has taken place, forming thin layers of olivine-rich rock near the bases of the sills; but in the picrite sills crystallisation must have been far advanced before the injection of the magma. Dr. Walker thinks that the evidence of these rocks tells against Dr. Kennedy's views as to the magmatic parentage of the British Kainozoic province (see above).

Dr. Walker has also shown that "The Dolerite Isles of the North Minch" (*Trans. Roy. Soc., Edin.*, LVI, pt. 3, 1931, pp. 753–66) consist of olivine-dolerites, crinanites, teschenites, and picrite-dolerites, which represent the northerly continuations of the great group of basic sills of Skye (see preceding par.). They formed a deep-seated phase of the igneous activity during which cooling was slow; and this resulted in crystallisation-differentiation both by gravitational settling of early olivine, and by injection of residual magma into rifts in the crystal mesh.

Dr. W. J. McCallien finds that the Kainozoic igneous rocks of Kintyre (*Geol. Mag.*, LXIX, 1932, pp. 49–61) belong to the olivine-dolerite—crinanite group, together with a teschenite, monchiquite, and camptonite, and members of the group of tholeiites and leidleites. He also discusses the distribution of the Kainozoic dikes in Arran, Kintyre, Islay, and Jura, and on what appears to be good evidence separates the Islay dikes from the Arran Swarm, assigning them to an assemblage which has its focus to the north-west of Islay in the region where the dolerite island of Dubh Artach is situated. This swarm, like the Arran Swarm, dies out to the south-east. Dr. McCallien also thinks that the crowded dikes of the south coast of Arran may belong to a focus situated between that island and Ailsa Craig.

The Loch Doon plutonic mass of Galloway, which has been described by C. I. Gardiner and S. H. Reynolds (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, pp. 1–34), occupies an area of 47 sq. miles. It consists mainly of tonalite, but ranges from a granite core to norite on the margins. These rocks are regarded as the results of three successive intrusions in order of decreasing basicity. The field evidence suggests that the mass has the form of a laccolith. It has a wide contact aureole consisting mainly of biotite-cordierite-hornfels, and some interesting rock types have been produced by the contact metamorphism of Arenig cherts. There are numerous minor intrusions surrounding the plutonic mass, some of which have been metamorphosed, and are therefore of pre-plutonic age.

The Lower Carboniferous igneous rocks of Northumberland are described by S. Tomkeieff, with two new analyses, in the Geologists' Association excursion memoir entitled, "Contributions to the Geology of Northumberland and Durham" (*Proc. Geol. Assoc.*, XLII, pt. 3, 1931, pp. 217–96). A summary of the petrography of the Late-Carboniferous and Tertiary intrusions of the district is given by A. Holmes and G. S. Mockler.

In a study of the dikes of the Ards Peninsula, Co. Down, Miss D. L. Reynolds (*Geol. Mag.*, LXVIII, 1931, pp. 97–111; 144–65) divides these intrusions into two groups—an older group consisting mainly of pyroxene-minettes, which were injected during a pause in the Caledonian folding and were subsequently crushed by a renewal of pressure; and a younger group of lamprophyres and porphyries, which were intruded at the close of the folding. Some of the latter were hornblende-bearing, others carried both hornblende and biotite. The majority of the dikes have a south-west to north-east trend, and are believed to be genetically connected with the Newry granite complex.

The fifth part of Prof. W. C. Brögger's great work on the igneous rocks of the Oslo region has been published under the title, "Der grosse Hurumvulkan" (*Norske Vidensk.-Akad., Oslo, I. Math.-Nat. Kl.* (1930), No. 6, 1931, 146 pp.). It deals with the essexitic lavas and plutonic rocks of the islands and nearby coasts in the central parts of the Oslo Fjord. These rocks are regarded as the products of a great shield volcano—the Hurum Volcano—of which the only remaining parts are the peripheral lava flows, and portions of the plutonic core. The lavas are essexitic basalts (? trachybasalts) and madeirites; the plutonic types are essexite-gabbro, essexite, yamaskite, pyroxenite, and cumberlandite, whilst there are numerous hypabyssal intrusions of the well-known Oslo types. The memoir contains twenty-five new chemical analyses.

An excellent summary and discussion of Brögger's memoir in its bearing on magmatic differentiation has been published by (the late) Prof. J. H. L. Vogt (*Norsk Geol. Tidsskr.*, **12**, 1931, pp. 541–62).

The Breven (Sweden) dolerite dike, of which T. Krokström has made an exhaustive petrogenetic study (*Bull. Geol. Inst. Upsala*, XXIII, 1932, pp. 243–330), is a massive igneous body about 30 kms. long and from 0·3 to 1·2 kms. wide. It is a composite mass consisting of olivine-dolerite, olivine-free dolerite, granophyre, and olivine-dolerite, in chronological order. It is believed that the presently visible part of the dike represents a section at intermediate depth through a fissure which served as a channel for a series of intrusions corresponding

to the above rock-types. The granophyre exerted a strong pneumatolytic effect upon the dolerite, changing it into an amphibole-and biotite-bearing, somewhat alkalic, intermediate rock which is called epidolerite.

In his illuminating summary and discussion of recent work on the Pre-Cambrian of Finland, Prof. F. von Wolff (*Geol. Rundsch.*, XXIII, 1932, pp. 89–121) deals with the differentiation of the Rapakiwi granites and Högland porphyries with the aid of his own method of projection of chemical analyses. A granodiorite of composition corresponding to the mean of the Högland porphyries is regarded as the primary magma, from which pyterlite (melanocratic Rapakiwi) and basalt split off. A later differentiation of the same focus gave rise to trachyte which, with pyterlite, formed a hybrid which is the Wiborg type of Rapakiwi. A normal gabbro-diorite-granodiorite-granite differentiation series characterises the magmas of the Svionian to Bothnian periods. The origin of the orbicular granites, in which Finland is so rich, is also discussed.

A dolerite intrusion in the Dutch Carboniferous, which was reached by boring at a depth of 970 metres, is described by S. Tomkeieff and P. Tesch (*Geol. Mag.*, LXVIII, 1931, pp. 231–6) as being very similar to certain types of the Whin Sill, and in particular to tholeiitic varieties of the quartz-dolerite magma. The Holland dolerite may therefore belong to the late Hercynian cycle of igneous activity which gave rise to quartz-dolerites and related rocks in several localities.

With the aid of sixteen new analyses Dr. C. Friedlander has described the principal types of igneous rocks in the Vosges, especially those of the Kamm Granite and the Hochfeld massif. Accessory phenacite has been established in the Andlau granite. Prof. P. Niggli deals with the chemical relations of these Hercynian igneous rocks on the basis of his well-known system of projection (*Schweiz. Min. Petr. Mitt.*, XI, 1931, pp. 365–411).

Following upon the discovery of riebeckite in a lamprophyre belonging to the typically " Pacific " Lausitz Granite association, Dr. E. Tröger (*Sitz. u. Abh. Naturwiss. Ges. Isis, Dresden, Jahrg.* (1931), 1932, pp. 159–67. Also, *Fortschr. Min. Krist. Petr.*, **16**, 1931, pp. 395–6) discusses the apparent intermingling of " Pacific " and " Atlantic " types among lamprophyres. He shows that under certain magmatic conditions camptonitic rocks may develop from a " Pacific " magma, but these are not so characteristic as the true " Atlantic " camptonites, and he would prefer to call the former " camptonitic spessartite."

Prof. E. Lehmann has described an interesting detailed section in the Middle Devonian igneous rocks of the Lahn-Dill region which occurs in the iron mine Königszug at Oberscheld (*N.J. f. Min., Abt. A. Beil.-Bd.*, **64**, 1931, pp. 549–92).

The section consists of keratophyre-schalstein which is divided into several zones according to degree of alteration, crushing into lenses, etc. It is bounded by diabase on both hanging wall and footwall, and cut by numerous dikes of soda-rich keratophyre. Many new and full chemical analyses of this spilitic series are given, and the paper is of much importance for discussion of the genesis of this series.

Numerous phonolites and leucite-basalts of Kainozoic age are described and chemically analysed in a memoir by R. Herri ("Petrographische und chemische Untersuchung junger Eruptivgesteine in der Umgebung von Oberwiesenthal im Erzgebirge," *Chem. d. Erde*, **4**, 1930, pp. 632–65).

A. Marchet has described the Pre-Sarmatian lavas of Gleichenberg (Oststeiermark) (*Sitz.-ber. Akad. Wiss. Wien. Math.-Nat. Kl. Abt. I.*, Bd. 140, Heft 7, 1931, pp. 461–540). They are found to consist mainly of trachyandesites and trachytes with a few rhyolites. They occur on the margin of the Pannonian subsidence, and appear to be tectonically connected with that structural feature.

H. Knorr's study of the differentiation and eruptive sequence of the Oligocene and Miocene igneous province in the Bohemian Mittelgebirge (*Min. Petr. Mitt.*, **42**, 1932, pp. 318–37) is based on von Wolff's new method of differentiation projections. Four eruptive phases are distinguished in order of age: (1) the older basalt and phonolite phase; (2) the essexite and tephrite phase; (3) trachyte and phonolite phase; and (4) ultrabasic basalts and lamprophyres. A calculated differentiation sequence starting with a basanitic magma agrees closely with the above age sequence.

A thorough mineralogical, petrological, and chemical study of the basalt fields of Lower Hesse and of the Rhön region by K. Heykes (*Jahrb. Preuss. Geol. Landesanst.*, **51**, 1930, pp. 469–504) discloses the essential similarity of these two petrographic regions. Von Wolff's methods have been used in the chemical comparisons.

The mineralogy and petrology of the well-known theralitic rocks of the Katzenbuckel have been exhaustively described by H. Nieland (*N.J. f. Min., Beil.-Bd.*, **63**, Abt. A., 1931, pp. 83–140). Their chemical study, especially of the rarer elements, has been further advanced by spectrographic methods in the hands of F. Schröder (*ibid.*, pp. 215–66).

In his paper entitled "A Classification of some Rhyolites, Trachytes, and Phonolites from part of Kenya Colony, with a note on some Associated Rocks," Dr. W. Campbell Smith (*Quart. Journ. Geol. Soc.*, LXXXVII, 1931, pp. 212–58) provides a valuable synopsis of the chemical and mineral characters of East African volcanic rocks of the Great Rift Valley region,

with many new chemical analyses. He describes soda-rhyolites of the Comende, Pantelleria, and Gibelé types, pantelleritic trachyte, kataphorite-trachyte, phonolites of the Kenya, Losuguta, and Kapiti types, and kenyte. The basalts of the region belong mainly to thoroughly alkalic types in harmony with the alkalic cast of the above-mentioned rocks.

The volcanic field of Toro-Ankole (Uganda), described by A. Holmes and H. F. Harwood (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, pp. 370–442) constitutes a highly individualised co-magmatic region the unity of which is demonstrated by the modes of occurrence, rock and mineral associations, and geochemical characters of the rocks. They consist mostly of tuffs with a few lavas, including such types as melilite-leucitite, leucitite, potash-ankaratrite, melilite-basalt, leucite-ankaratrite, biotite-pyroxenite, potash-nephelinite, and olivine-leucitite. Analyses show that the biotite-pyroxenite is heteromorphic with certain leucitites, and mica-peridotite with olivine-leucitite. The remarkable petrological and geochemical inferences drawn from this bizarre suite of igneous rocks must be dealt with on another occasion. It must suffice to say here that Prof. Holmes derives the rocks by differentiation from the primary peridotite stratum of the subcrustal region.

The volcanic rocks of Mt. Elgon in British East Africa, described by O. H. Odman (*Geol. För. Förh. Stockholm*, **52**, 1930, pp. 455–536), consist of lavas styled nephelinite, melilite-nephelinite, melilite-nepheline-basalt, phonolitic nephelinite, and phonolite, with dike rocks comprising melilite- and nepheline-bearing lamprophyres such as bergalite. This assemblage, as noted by Prof. Holmes, has marked resemblances to that of the Toro-Ankole region of Uganda.

The Brandberg is one of three important plutonic centres in South-west Africa, which are, in all probability, of later date than the Karroo lavas. Its structure and tectonic relations have been described by Prof. H. Cloos, and its petrography by K. Chudoba (*N.J. f. Min., Beil.-Bd.*, **66.**, Abt. B., 1931, pp. 1–82; 83–130). The Brandberg consists mainly of a stock of alkali-granite, together with dikes of aplite (a new variety called brandbergite), diabase, and melaphyre, and remnants of lava flows styled melaphyre, hornblende-porphyrite, and quartz-porphyry. The whole province shows marked alkaline affinities.

The large quarto memoir by L. Barrabé entitled: "Contribution a l'étude stratigraphique et pétrographique de la partie médiane du pays Sakalave (Madagascar)" (*Mém. Soc. Géol. France* (*N.S.*), tom. V., Fasc. 3–4, Mém. No. 12, 1929, pp. 1–270) contains some fifty pages dealing with varied suites

of igneous rocks belonging to the Permo-Triassic, Jurassic, Middle and Upper Cretaceous. No detailed petrographical or chemical study has, however, been attempted.

A paper by A. Rittmann on rocks from Kellang and Manipa (Ceram) describes a series of late-Mesozoic eruptive rocks consisting of peridotite and serpentine, gabbros, quartz-diorite, aplites and pegmatites, which have been injected into a roof of schists and Mesozoic sediments, and have formed a series of resorption- and injection-gneisses. A hypersthene-basalt, probably of late-Tertiary age, is also described. The analysis of this rock, showing 53 per cent. of silica, suggests that hypersthene-andesite would be a more appropriate name (*Geol. Petr. and Pal., Results of Explorations in Ceram,* First Ser., Petr., No. 2, 1931, 71 pp.).

T. Ichimura describes a series of alkaline rocks intruded into the Miocene of the frontier region near Kainei, Korea (*Mem. Fac. Sci. & Agric. Taihoku Imp. Univ.*, III, No. 3; *Geology*, No. 1, 1931, pp. 215–47). They occur as laccoliths, sills, and dikes, and consist mainly of trachydolerite, from which differentiation-products such as olivine-trachybasalt, basanite, and alkali-gabbro have been derived. An alkali-syenite occurs as dikes and patches in trachydolerite. Primary analcite and natrolite are found in these rocks, which closely resemble the teschenite, crinanite, and analcite-syenite of the West of Scotland.

The report of the Alkaline Rocks of Australia and New Zealand Committee (*Rept. Aust. Assoc. Adv. Sci.*, XVIII, 1926, pp. 36–45), which has only recently come to hand, contains some interesting petrological material, including twelve analyses of alkali feldspars in Victorian basalt vent debris, and three new rock analyses. The most striking new point, which is of great interest in view of Prof. Holmes's work mentioned above, is the occurrence of richly-potassic leucite-bearing rocks in some agglomerate plugs of Western Australia. These rocks, like the Central African, are remarkable for very high percentages of titanium and barium.

Prof. E. W. Skeats has made a useful survey of the age, distribution, and petrological characters of the granites of Eastern Australia (*Proc. Roy. Soc. Vict.*, XLIII, pt. 2 (N.S.), 1931, pp. 101–19). He also discusses their areal distribution, the association of granites with periods of severe mountain folding and with the directions of fold and fault movements, the association of soda-rich intrusions with particular geological periods, and the relations of certain granite intrusions to the occurrence of metallic minerals.

Rock specimens from Thule Island, the southernmost member of the arc of the South Sandwich Islands, turn out to

be dacites and andesites which, as shown by microscopical and chemical characters, are of typical Andean affiliations (G. W. Tyrrell, *Discovery Reports*, III, 1931, pp. 191–7). This fact is confirmatory of E. Suess's view of the " South Antillean Arc " of folding as an enormous loop of Andean structures extending eastwards into the heart of the alien tectonic region of the South Atlantic Ocean.

Probably the most outstanding petrological memoir of 1931 is R. Balk's " Structural Geology of the Adirondack Anorthosite—A Structural Study of the Problem of Magmatic Differentiation " (*Min. Petr. Mitt.* (N.F.), **41**, 1931, pp. 308–434). The main rock types of this colossal intrusion are gabbro, anorthosite, and syenite. The parental magma is believed to have been intermediate between gabbro and syenite. It was intruded slowly from the south-eastern edge of the Canadian Shield, advancing towards the south-west as an upwardly directed, expanding, and thinning wedge of magma. The liquid was highly viscous and contained suspended crystals of labradorite and a smaller number of ferromagnesian minerals. The principal factor in the early differentiation of the intrusion into anorthosite and gabbro was friction against the walls of the magma chamber, the suspended solid crystals being retarded with respect to the liquid. The small crystal clusters formed by this action grew into layers, lenses, and irregular bodies with the slow advance of the intrusive wedge. Hundreds of small spherical bodies of gabbro are found in the north-eastern part of the mass. These were formed by the " balling " of ferromagnesian mineral clusters which, as groups, sank diagonally downward as the resultant of gravity and the forward movement of the magma. The labradorite crystals, however, did not ball up, and were drifted forward to form the main central mass of anorthosite. Syenite was the residual liquor which had been expressed to the south-west in advance of the increasingly viscous anorthosite, which shows protoclastic structures. The above remarkable results have been arrived at by study of the distribution and mutual age relations of the constituent rocks, the mode of crystal separation, the effects of conditions of intrusion on the differentiation of the three main rock types, and the structural lines of the magmatic body and its frame of Grenville rocks.

Discussing the " Adirondack Magmatic Stem," Dr. A. F. Buddington (*Journ. Geol.*, XXXIX, 1931, pp. 240–63) is of the opinion that the anorthosite is due to gravitative sorting of crystals in a deep-seated chamber, aided by subsequent filtration differentiation during emplacement at a higher level. A comparative study of the Adirondack assemblage yields evidence for the conclusion that it may be ascribed to a pyroxene

line of descent in the earlier stages of differentiation, and a hornblendic line in the later stages. Differentiation seems to have proceeded in a much drier magma than that of the common granodiorite series (*e.g.* Sierra Nevada), but in somewhat wetter magma than the pyroxenic Bergen-Jotun series.

The " Adirondack Anorthosite and Its Problems " have also been discussed by H. L. Alling (*Journ. Geol.*, XL, 1932, pp. 193–237).

W. J. Miller describes a mass of anorthosite in Los Angeles, Co. Cal. (*Journ. Geol.*, XXXIX, 1931, pp. 331–44). He compares it with other anorthosites, notably that of the Adirondacks. He regards the intrusion as due to crystallisation differentiation from an original gabbro magma, and believes that the anorthosite was emplaced in a truly intrusive manner at a later stage of cooling.

According to A. L. Anderson and V. R. D. Kirkham (*Amer. Journ. Sci.* (5), XXII, 1931, pp. 51–68) alkaline rocks of the Highwood type occur as sills and dikes in south-eastern Idaho. Magmas of the Highwood type are especially rich in potash, and at the same time are high in lime. Monzonite, shonkinite, syenite, quartz-monzonite-porphyry, and granite-porphyry are the chief rock types described.

The rocks of the Shonkin Sag laccolith, that classic example of differentiation in place, have been re-studied by F. F. Osborne and E. J. Roberts (*Amer. Journ. Sci.*, XXII, 1931, pp. 331–53), with the aid of three new analyses. The authors come to the conclusion that differentiation in Shonkin Sag was accomplished chiefly by gravitational settling of olivine and augite in the original magma, and of augite crystals which formed in place. The composition of the border facies closely approximates to the average composition of the rest of the laccolith.

To explain the basic hornblende-rich and pyroxenic inclusions in the dacites of Lassen Peak and vicinity (Cal.), Dr. Howel Williams (*Amer. Journ. Sci.*, XXII, 1931, pp. 385–403) supposes that at the roof of the magma chamber a solid crust (or rather sponge-like aggregation) had developed, consisting chiefly of hornblende and basic feldspar, with parts in which pyroxenes had formed instead of hornblende. On eruption of the fluid magma below this dacitic crystal sponge was disrupted and carried up as inclusions. It is noteworthy that it is the later lavas and volcanic domes which carry the most inclusions. The protrusion of the Lassen domes thus probably occurred after a long period of crystallisation in the magma chamber below, and the violent explosions by which they are usually heralded are due to the high concentration of volatiles in the residual liquid.

Dr. R. E. Fuller's memoir on "The Geomorphology and Volcanic Sequence of Steens Mountain in South-western Oregon" (*Univ. of Wash. Publ. in Geol.*, **3**, No. 1, 1931, pp. 1–130) contains a large quantity of petrographic data on the Tertiary basalts, andesites, and rhyolites which build up the mountain, although its main theme is volcanism. Twenty-eight new chemical analyses are published in this memoir. Doubtless the full petrological treatment of this abundant material is reserved for a later paper.

H. S. Washington and M. G. Keyes describe the lavas of the wholly volcanic Pribilof Islands in Bering Sea as mostly basalts with or without olivine (*Amer. Journ. Sci.* (5), XX, 1930, pp. 321–38). Nepheline-basanite occurs on St. Paul Island, and trachyte on St. George. This association of alkaline rocks with greatly predominating basalts is compared with the similar relations that hold in the Pacific islands.

The theme of T. W. F. Barth's comprehensive paper on "Mineralogical Petrography of Pacific Lavas" (*Amer. Journ. Sci.* (5), XXI, 1931, pp. 377–405; 491–530) is the complete record of the mineralogical, chemical, and petrographical data regarding the lavas in question. Characteristic of these Pacific lavas is the almost total absence of orthorhombic pyroxenes, and extreme scarcity of hornblende and biotite. Both coloured and colourless constituents fall into reaction series, and the sequence of crystallisation is parallel to the sequence of differentiation. Bowen's theory of differentiation by crystal settling is regarded as adequate to explain the variations in Pacific lavas.

ZOOLOGY. By Prof. F. W. Rogers Brambell, B.A., Ph.D., D.Sc., University College of N. Wales, Bangor.

The developmental history of the Primates was dealt with by J. P. Hill in the Croonian Lecture for 1929. The text of this lecture, recently published (*Phil. Trans. Roy. Soc.*, B. **221**, 1932), deals with the early embryology and placentation of the Primates and the light they throw on the evolution of the group. This paper provides an authoritative review of our knowledge of the earlier stages of development and the formation of the placenta in the Primates. In it the earlier work is discussed and much new material described. The author, in addition to describing material in his own collection, has reinvestigated much of that previously described by other authors, including the famous Hubrecht collection. The paper is very beautifully illustrated with text-figures and over twenty half-tone plates.

Four main stages in the evolutionary history of the order, based on the embryological finding, are recognised, *viz.* a Lemuroid, a Tarsioid, a Pithecoid, and an Anthropoid stage.

The living Lemurs, as representative of the first stage, exhibit primitive features together with others which are more advanced and which foreshadow the conditions found in higher Primates. They are primitive in the mode of formation of the blastocyst, in the central type of development, in the early exposure of the embryonal ectoderm, in the formation of the mesoderm, in the development of the amnion by folds, in the outgrowth of the allantois as a free vesicle and in the placentation. The early formation of a complete chorion, its direct vascularisation by the allantoic vessels, and the reduction of the yolk-sac are more advanced features. Tarsius, representing the next stage, is primitive and resembles the Lemurs in the exposure of the embryonal ectoderm and in the development of the amnion by folds. It is more advanced and is anticipatory of the Pithecoids in the still more precocious formation of the extra-embryonal mesoderm, cœlom, and chorion and in the presence of an almost solid connecting stalk instead of a vesicular allantois. Direct attachment of the blastocyst to the uterine lining constitutes another advance on the condition in the Lemurs and leads to the formation of the massive discoidal placenta of the deciduate hæmochorial type. It is concluded, however, from the unique character and behaviour of the trophoblast that the placenta is too specialised for Tarsius to have been the direct forerunner of the Pithecoids.

The Platyrrhine and Catarrhine Monkeys exhibit certain striking resemblances, all in the nature of definite advances on the Tarsioid condition. The amnion arises very early as a closed space in the ectodermal cell-mass. The blastocyst becomes attached to the uterine wall first by the trophoblast of the embryonal pole and usually later by the anti-embryonal pole, when a bi-discoidal placenta is formed. The extra-embryonal mesoderm and cœlom and the connecting stalk are formed even more precociously than in Tarsius. The trophoblast differentiates into cellular and syncytial layers and the latter penetrates the maternal decidua. The presence of certain differences in the trophoblast and in the placenta of the Platyrrhines and Catarrhines and the similarities in the development of the placenta in the latter group and in the Anthropoids suggest that the Platyrrhines separated early from the parent stem and that the Catarrhines gave rise to the Anthropoids.

Knowledge of Anthropoid development depends chiefly on that of man, but later embryonic stages and the placentation of the Anthropoid Apes warrant the assumption that they are essentially similar. In man we find the culmination of developmental adaptation among the Primates, the outstanding feature of which is the extraordinary precocity of the early blastocyst,

and the manner in which it becomes embedded in the maternal decidual tissue. The interstitial implantation of the ovum results in certain specialisations distinctive of the Anthropoids, but apart from these they develop along the lines laid down in the Catarrhines, of the genetic relationship of which there can be no question.

The structure of the climbing organ of the reduviid bug, *Rhodnius prolixus*, is described in a paper by Gillett and Wigglesworth (*Proc. Roy. Soc.*, B., **111**, 1932). The organ is situated at the distal end of the tibia on the first and second pairs of legs in the adults of both sexes, but is absent in the nymphs. It is much more efficient for climbing upwards than downwards. The organ is a little blood-filled sac of soft chitin with some 5,000 tubular hairs, which are the outlets of unicellular oil glands, on its lower surface. The free ends of these hairs are cut obliquely, the hind margin only of each hair coming in contact with the surface. About fifty sensory hairs are scattered among the climbing hairs. They are tapering and slightly longer than the others. It is shown that a model consisting of a disc separated from a glass plate by a wedge of oil can be moved easily in the direction of the open end of the wedge, but offers considerable resistance to movement in the opposite direction. The resistance to movement in the direction of the point of the wedge is due to seizure of the two surfaces, caused by the breakdown of the oil film at the point of the wedge. It is suggested that the hairs of the climbing organ of Rhodnius act in a similar manner to such a model.

The arrangement and behaviour of the chromosomes during spermatogenesis in the Hemipteran, *Alydus calcaratus*, are described in a large monograph by Reuter (*Acta Zool. Fennica*, **9**, 1930).

The chitin lining the fore-gut of decapod Crustacea and the function of the tegumental glands is the subject of the first of a series of papers by Yonge (*Proc. Roy. Soc.*, B., **111**, 1932) on the nature and permeability of chitin. It is shown that the lining of the fore-gut consists of a thin superficial cuticle and a thick underlying chitin. The cuticle is chemically distinct from chitin. At ecdysis the new chitin is formed by the chitogenous epithelium. The cuticle is formed in the tegumental glands, the structure of which is described, flowing through their ducts, which open on the external surface of the chitin, and spreading over the surface of the chitin as a thin film which solidifies. After the formation of the cuticle the tegumental glands degenerate and new ones are formed immediately. The spreading of the newly formed cuticle over the surface is probably due to its low surface tension. The cuticle extends everywhere over the surface of the chitin, and the

tegumental glands also occur everywhere beneath the chitin. It is thought that the cement which binds the eggs to the appendages of the female is a similar substance to the cuticle and is produced by the tegumental glands of the pleopods. The presence of a cuticle and of the tegumental glands appears to be universal throughout the Crustacea, probably throughout the Arthropoda.

The innervation of the heart of Decapod Crustacea is the subject of a paper by Alexandrowicz (*Q.J.M.S.*, **75**, 1932). Three systems of nervous elements were distinguished in the heart of Decapoda, *viz.* (*a*) a local system of neurons which are distributed in the heart itself; (*b*) a system connecting the heart with the central nervous system; and (*c*) a system supplying the valves of the arteries arising from the heart and the muscles of the pericardium. The local system consists of a main ganglionic trunk on the dorsal wall of the heart, which sends branches to the muscle fibres of the heart. This ganglionic trunk contains five large and four small nerve-cells in three forms investigated, and this number probably does not vary much in marine Decapoda. The fibres connecting the heart with the central nervous system arise from the infra-œsophageal ganglion and run to the dorsal surface of the heart, where they come into relation with the local nervous system. The system of nerves innervating the valves of the main arterial trunks consists of, (*a*) four nerves on each side arising from the thoracic nerves which join to form one or two longitudinal bundles giving off branches to the valves of the paired antennary and hepatic arteries and the median posterior aorta; (*b*) a nerve arising from the stomatogastric nerve and supplying the valves of the median anterior aorta. In addition to these three systems of nerves supplying the heart branches from the thoracic nerves enter the pericardial cavity and break up into neuropile-like networks on the ligaments of the heart and on the connective tissue covering the dorsal wall of the heart. Regarding the function of these elements, it is suggested that the local system is an "autonomic" system from which the heart muscles receive the impulses for their regular contractions. The dendrites of the cells of this system were found to end in the muscles also, suggesting, further, that the rhythmical discharges of these nerve-cells are influenced by the rhythmical action of the muscles, thus securing a reciprocal regulation in the two parts of the cardiac neuromuscular mechanism. It is thought that the second system of dorsal nerves performs inhibitory and acceleratory functions while the nerves to the arterial valves cause contraction of their muscles when the heart is in diastole. Finally, the nerves ending in fine networks in the pericardial cavity are evidently sensory in function.

The development of that very interesting creature, the *mitraria* larva of *Owenia*, is described and beautifully figured in a paper by Wilson (*Phil. Trans. Roy. Soc.*, B., **221**, 1932). The larvæ of *Owenia fusiformis* were obtained chiefly by artificial fertilisation and were reared successfully through metamorphosis and for about a month afterwards. The trochosphere stage is attained about two days after fertilisation, and the larva is ready to metamorphose about a month later. Prior to metamorphosis, the trunk and head rudiments are forming within the larva, the trunk being partly invaginated. The various larval stages are described in detail and carefully figured, but the chief interest centres around metamorphosis, which is cataclysmic. At metamorphosis the trunk straightens out and its anterior everted segments are inverted. The stomach and œsophagus are simultaneously dragged into the anterior segments. The larval tissues break away from the head and trunk, and the head, which is now separate, is pulled down to the trunk, with which it fuses. A new mouth is formed by the breaking across of the œsophagus behind the old larval mouth. The long provisional bristles of the larva fall off, the larval chæta-sacs invaginate, and the larval tissues, which have separated from the adult tissues, break up and are swallowed by the young worm. Extensive and revolutionary as these changes at metamorphosis undoubtedly are, they take place in about thirty seconds. The young worm is busy swallowing the remains of the larval tissues and at the same time secreting a mucus tube less than one minute after the fully formed mitraria larva began metamorphosis. Unfortunately, this study of the mitraria does not appear to throw any light on the affinities of that remarkable group of worms, the Oweniidæ, but it is suggested that investigation of the larvæ of Maldanid worms, of which no undoubted example has been described hitherto, might help to elucidate this problem.

The anatomy and histology of the alimentary canal of the Limpet, *Patella vulgata*, are described in detail in a paper by Graham (*Trans. Roy. Soc. Edin.*, **57**, 1932). The physiology of digestion is also investigated and it is shown that the food of Patella, consisting of diatoms and algæ, is conveyed to the fore-gut by the radula and is at the same time lubricated by the saliva, which contains no enzymes. Cells of the lateral diverticulæ of the fore-gut secrete an amylase, which is mixed with the food in the gut by means of ciliary currents. The digestive gland secretes a protease and other cells in it absorb the food. The residue in the hind-gut is worked up into fairly rigid rod-like fæcal masses.

The fæcal pellets of a number of the commoner British marine Mollusca have been described and figured by Moore, who

deals with those of the Anomura in a recent paper (*Proc. Roy. Soc. Edin.*, **52**, 1932). These investigations have been carried out with a view to determining the origin of the various fæcal pellets found in marine deposits and also as a possible source of light on the relationships of allied species and genera. The types already described exhibit a wide range of form, rod-like, with or without transverse, longitudinal or spiral patterns externally, ribbon-like, or bead-like. In the Anomura the pellets are rod-like with simple or no external sculpturing. Internally, however, the pellets are complicated by the presence of longitudinal canals, varying in number from four to several hundreds. In some the structure is further complicated by the crescentic shape of the canals in cross-section and by the presence of a ventral cap of fine material on the pellet. The physiological significance of this complicated structure is discussed, as is also the bearing of the structure of the pellets on the origin and affinities of the various members of the group. Moreover, a knowledge of the structure of the fæcal pellets of invertebrates is of geological importance, since such pellets may be found fossilised in suitable deposits and may throw some light on the animals which produced them.

The eggs of marine invertebrates are known to maintain a state of osmotic equilibrium with the environment. Their surface appears to act as a semi-permeable membrane, since water enters or leaves the cell following changes in the concentration of osmotic substances in the environment. The eggs of birds and of fresh-water animals, both vertebrate and invertebrate, on the other hand, maintain much higher concentrations of osmotic substances within the cell than those prevailing without. The problems thus presented by unfertilised hens' eggs have been investigated by Straub (*Rec. Trav. Chim. des Pays Bas.*, **48**, 1929) and by Needham (*Jour. Exp. Biol.*, **8**, 1931), who found a difference of about two atmospheres between the osmotic pressure of the yolk and white. Recently Bateman (*Jour. Exp. Biol.*, **9**, 1932) has confirmed the finding of a real osmotic difference between the white and yolk of the hen's egg. Straub suggested that this difference is maintained by the performance of osmotic work by the vitelline membrane, but Hill (*Trans. Farad. Soc.*, **26**, 1930) has shown that if work is performed at all, it depends on anaerobic processes. Needham and Smith (*Jour. Exp. Biol.*, **8**, 1931), discussing this problem, show that it is improbable that work is performed to maintain this steady state. Much light is thrown on the problem by an investigation of the osmotic properties of the eggs of the trout (*Salmo fario*) by Gray (*Jour. Exp. Biol.*, **9**, 1932). These eggs resemble those of the hen in that the osmotic concentration ($\Delta = -0{\cdot}48^\circ$ C.) within the cell is much greater than that of the

surrounding medium (tap-water, $\Delta = -0{\cdot}02^\circ$ C.) and that this difference is maintained in the unfertilised eggs over long periods, although the oxygen consumption is too small to be measured by ordinary methods. It is shown that neither water nor salts pass across the inner or vitelline membrane of the normal trout's egg in measurable quantities. The impermeability of this membrane therefore maintains the normal hypertonicity of the cell without the expenditure of energy. It is suggested that it is not impossible that this state of impermeability also characterises the normal healthy hen's egg.

The relation of iodine compounds, and thyroxine in particular, to fertilisation is the subject of a series of papers by Carter, the earlier parts of which appeared some months ago and are now followed up by further investigations (*Jour. Exp. Biol.*, **9**, 1932). Lillie (1914) showed that echinoderm eggs washed in a current of sea-water rapidly became unfertilisable owing to the loss of egg secretions, and particularly of the substance which he called "fertilizin." Carter (*Jour. Exp. Biol.*, **8**, 1931) showed that washed eggs remain fertilisable longer if thyroxine is present in the sea-water. It was suggested on the strength of this and other similarities in the action of thyroxine and the egg secretions that the former is chemically related to some substance (probably fertilizin) which is present in the latter. If this is so, thyroxine may definitely replace the fertilizin in the cytoplasm, probably by being transformed into it within the cell. On the other hand, the prolongation of the fertilisable life of the washed eggs by thyroxine might be due to the drug lowering the permeability of the egg surface and so retarding the loss of the egg secretions. In the fourth of this series of papers, Carter (*Jour. Exp. Biol.*, **9**, 1932), dealing with the effect of thyroxine on the capacity for fertilisation in washed and unripe echinoderm eggs, shows that the former is the true explanation. He confirms the observation that eggs becoming unfertilisable owing to washing are improved by treatment with egg-water. This is found to be true of both *Echinus esculentus* and *E. miliaris* and, moreover, egg-water of the opposite species is also effective. It is shown that the thyroxine has a similar action and is as effective as egg-water. It must therefore be replacing the secretions which have been lost already and not merely retarding the rate of loss. Unripe eggs are also improved by treatment with either egg-water or thyroxine. It is shown that these effects are due to the action on the eggs, not on the sperms, and that they are not due to variations in the H-ion concentration or osmotic pressure.

The egg secretions are also known to produce activation of the sperms and to prolong their active lives. In both these

respects Carter has shown (*Jour. Exp. Biol.*, **7**, 1930, and **8**, 1931) that thyroxine produces a similar effect. Lillie (*Jour. Exp. Zool.*, **16**, 1914) showed that egg secretions also produced agglutination of the sperms. This is known to be due to the presence in the secretions of either an iso-agglutinin or a hetero-agglutinin or both. The iso-agglutinin causes a non-toxic, temporary, and reversible agglutination of the sperms of the same species. It is colloidal and is either identical with or closely related to fertilizin. The hetero-agglutinin causes permanent, irreversible, and usually toxic agglutination of foreign sperm. It is thus non-specific while the iso-agglutinin is specific. Carter (*Jour. Exp. Biol.*, **9**, 1932) has therefore investigated the effect of thyroxine in producing agglutination of the sperms. It is found to produce permanent agglutination of the sperms of many species. The sperms also exhibit chemotaxis towards the crystals of thyroxine in the sea-water. The agglutination caused by thyroxine thus resembles that produced by the hetero-agglutinin rather than the iso-agglutinin.

The several different and striking similarities, referred to above, in the action of thyroxine and the egg secretions of echinoderms during the processes which lead to fertilisation suggest that a chemical similarity exists. Following this line of reasoning, Carter (*Jour. Exp. Biol.*, **9**, 1932) extracted ripe ovaries and testes of *E. esculentus* by means of Harington's extraction method. The amount of crude extract obtained in this way was approximately one-eighth of the amount obtained by Harington from a similar quantity of thyroid. Although it was found that these extracts did not contain a large proportion of thyroxine, they had a small but definite metamorphic effect on amphibian tadpoles. These extracts were found to be active in producing the effects on echinoderm eggs and sperms. This activity was not due to the presence of a small proportion of thyroxine but to a much larger proportion of a chemically related substance. This substance is less efficient than thyroxine in accelerating amphibian metamorphosis but is more efficient than thyroxine in its effect upon echinoderm eggs and sperms. It is concluded that this substance is one of the components of the egg secretion and is the fertilizin of Lillie. It is also present in ripe sperms.

The results recorded in the previous papers are summarised and discussed by Carter (*Jour. Exp. Biol.*, **9**, 1932) in the seventh of this series of papers. It is suggested that the results fall into line if it is assumed that the hetero-agglutinin is a substance closely related to thyroxine and that the iso-agglutinin (= fertilizin ?) is a more complex substance of which the hetero-agglutinin is an essential component.

Carter (*Jour. Exp. Biol.*, **9**, 1932) has carried out further experiments on the effects of thyroxine on the sperms of the rabbit with a view to determining if compounds related to thyroxine may not play a similar part in the phenomena of fertilisation in animals other than echinoderms. Since the sperms were completely activated in all the media used, the duration of maximum activity as shown by the oxygen consumption was used as a criterion. It was found that the oxygen consumption of sperms obtained from the vas deferens and cauda epididymis was maintained at its initial value for a maximum time when the *p*H of the medium was 7·8–8·0. The initial consumption was unaltered, but the duration of active life was decreased on either side of the optimum *p*H but within the range 6·4–9·0. The behaviour of the sperms was unaffected by the presence of thyroxine in media of optimum *p*H. The presence of thyroxine lengthened the active life of sperms in media on either side of the optimum hydrogen-ion concentration. In both these respects the effect of thyroxine on the rabbit sperms resembled that on the "ripe" echinoderm sperms.

Following up recent investigations on the distribution of the phosphagens in the animal kingdom, Needham *et al.* (*Jour. Exp. Biol.*, **9**, 1932) have investigated three species of Protozoa with a view to determining if these substances are present in them, as they are in the metazoa. This point is of considerable interest, since their presence would suggest a relation between phosphagen metabolism and ciliary movement, such as has been established for muscular movement. The three species chosen were suitable for culturing in quantities sufficient for analysis of the phosphagen content. One, Glaucoma, is a holotrichous ciliate possessing myonemata and an undulating membrane; the other two, Bodo and Polytoma, are flagellates. No phosphagen was found to be demonstrable in them. This negative result raises the highly interesting problem of the source from which the energy for their movements is derived.

Part VI of the *Natural History of Wicken Fen* (Cambridge, 1932) brings the volume under the editorship of Prof. J. Stanley Gardiner to a close, thus completing the preliminary survey of the chief elements of the fauna and flora of the fen. This initial work on one of the most interesting properties held by the National Trust paves the way for extensive ecological investigations which, it is hoped, will be carried out in the future. No doubt further investigations will result in large additions being made to the list of the animals and plants of Wicken Fen, but this does not detract from the magnitude of the work which Prof. Gardiner and his colleagues have achieved during ten years of more or less continuous effort.

ENTOMOLOGY. By H. F. Barnes, M.A., Ph.D., Rothamsted Experimental Station, Harpenden.

General Entomology.—Various books have appeared recently and have been mentioned elsewhere.

An important review article on terrestrial insects and the humidity of the environment has been written by P. A. Buxton (*Biol. Rev.*, **7**, 1932, 275–320). This paper should be read by all interested in ecological work, it will naturally be read by insect physiologists. The same author has discussed the methods of estimating the weight of skeletal tissues in insects (*Biochem. Jl.*, **26**, 1932, 829–32). Recent developments in our knowledge of temperature and humidity in relation to problems of insect control have formed the subject of an address by A. D. Imms (*Ann. App. Biol.*, **19**, 1932, 125–43). The experimental study of these two factors is emphasised.

A review of the facts and theories bearing on the causes of abnormal segmentation is given in a note on the occurrence of spiral segmentation in *Apantesis nais* (Lep., Arct.) by E. T. Learned (*Jl. N.Y. Ent. Soc.*, **40**, 1932, 167–82). F. Brocher (*Archiv. Zool. Exp. et Gen.*, **74**, 1931, 25–32) has given a summary of his researches on the mechanism of respiration and blood circulation in insects, with references to the original papers.

Following the recent work of T. Goodey on *Tylenchinema oscinellæ*, a nematode parasite of the frit-fly, it is of great interest to hear that another fly, *Scatopse fuscipes* de Meij., is subject to attack by a nematode. P. Bovien (*Vidensk. Medd. fra Dansk. naturh. Foren.*, **94**, 1932, 13–32) has described *Scatonema wülkeri* gen. et sp. n. as parasitic in the body cavity of this fly. He has proved that copulation takes place and also that it may occur in the body cavity of the host or even inside the maternal uterus. Similarly U. S. Sharga (*Parasitology*, **24**, 1932, 268–79) has described a new nematode, *Tylenchus aptini*, which was found parasitising *Aptinothrips rufus* near Edinburgh.

In a report on investigations on the buffalo fly, *Lyperosia exigua* de Meij., and its parasites in Java and Northern Australia by E. Handschin (*Australian Council Sci. and Ind. Res.*, Pamphlet 31, 1932, 24 pp.), a brief account is given of some genetical experiments which were carried out with the Pteromalid parasite *Spalangia*. The *Lyperosia* race of *S. sundaica* was crossed with normal *S. orientalis*. The result was that females of the latter when crossed with males of the former live twice as long as normally and lay three times as many eggs. The reverse cross has the opposite effect.

D. S. Maclagan, in a paper dealing specially with insects (*Proc. Roy. Soc. London, B.*, **111**, 1932, 437–54), has shown that

the effects of population density are of greater significance than is generally realised. This is of particular interest now that so much attention is being paid to migration and the epidemiology of insect pests.

An annotated list of the insects and arachnids affecting the various species of walnuts (*Juglans*) has been compiled by R. E. Barrett (*Univ. Calif. Publ. Entom.*, **5**, 1932, 275–309). The original habitat and hosts of *Diatræa*, *Castnia* and *Tomaspis*, three major pests of sugar cane in tropical America, are described by J. G. Myers (*Bull. Ent. Res.*, **23**, 1932, 257–71). His account of the preliminary work in connection with the biological control of West Indian insect pests was noticed in these Advances last January. B. M. Hobby (*Jl. Animal Ecology*, **1**, 1932, 77–82) has made a study of the prey of a single community of *Dioctria rufipes* De G. (Asilidæ).

L. H. Dunn (*Psyche*, **39**, 1932, 26–9) has described a method for collecting ectoparasites from live animals and birds. The principle is to chloroform the parasites while the host is held in a container; the parasites are then easily collected from the bottom of the receptacle or combed from the hair of the animal.

Orthoptera.—Part 3 of the *Bull. Ent. Res.* (**23**, 1932, 293–424) is given over entirely to an exceedingly important paper on the phases of locusts in South Africa by J. C. Faure. A striking feature of this work is the change of colour by locusts experimentally reared in differently painted boxes. This change of coloration, however, is overwhelmed by crowding, isolated individuals exhibiting invariably the different colours of *solitaria* hoppers, while whenever the hoppers were crowded they acquired the *gregaria* type of coloration.

A determination of total blood volume in the cockroach, *Periplaneta fuliginosa* Serville, has been made by J. F. Yeager and O. E. Tauber (*Ann. Ent. Soc. America*, **25**, 1932, 315–27). Special attention has been paid to method.

L. Chopard (*Archiv. Zool. Exp. et Gen.*, **74**, 1932, 263–86) has dealt with the cave-inhabiting Orthoptera of the palæarctic fauna.

Coleoptera.—C. A. Thomas (*Ent. News*, **43**, 1932, 149–55) has now dealt with the diseases, bacterial and fungal, of the Elateridæ. Previously he has written papers on their parasites (*loc. cit.*, **40**, 1929) and their predators (*loc. cit.*, **42**, 1931). A remarkable wireworm double monster (*Limonius canus* Lec.) is reported by C. E. Woodworth (*Psyche*, **39**, 1932, 37–40).

T. Park (*Ecology*, **13**, 1932, 172–81), in a study of the relation of numbers to initial population growth in the flour beetle *Tribolium confusum* Duval, has shown that an optimum population-medium relationship exists in the early stages of

cultures in which two pairs of adult beetles in 32 grams of flour typically produce more eggs per day than in other cultures. K. Mellanby (*Proc. Roy. Soc. London, B.*, **111**, 1932, 376–90) has proved, after studying the effect of atmospheric humidity on the metabolism of the fasting mealworm, that the beetles are adapted to hot dry conditions and their water balance is upset when they are starved in moist air.

The information regarding the flea beetles living on cereals has been collected together by H. Blunck (*Zeit. f. angew. Ent.*, **19**, 1932, 357–94). A note has appeared by H. Scott on the use of the hind legs as weapons by the males of *Deporaus betulæ* L. (*Ent. Mon. Mag.*, **67**, 1931, 241–3). S. G. Jary (*Jl. S. E. Agric. Coll., Wye*, **30**, 1932, 171–82) has given an account of the strawberry blossom weevil, *Anthonomus rubi* Hebst. The bionomics of the pine-bark beetle, *Hylastes ater*, in New Zealand, have been dealt with by A. F. Clark (*N.Z. Jl. Sci. and Tech.*, **14**, 1932, 1–20).

Lepidoptera.—W. T. M. Forbes (*Amer. Nat.*, **66**, 1932, 452–60) in an essay on the age of this order comes to the conclusion that the Lepidoptera probably arose in the late Carboniferous or early Permian period and in a sort of symbiosis with the first flowers. This opinion is contrary to the one generally held that the Lepidoptera are the youngest of the larger orders.

An interesting biography of the Angoumois grain moth has been written by P. Simmonds and G. W. Ellington (*Ann. Ent. Soc. America*, **25**, 1932, 265–81). They trace its progress as a serious pest right up to the stage where it can be regarded as a beneficial insect of first rank owing to its use as the breeding medium of *Trichogramma*.

The structure and operation of the reproductive organs of the genera *Ephestia* and *Plodia* have been studied in detail (*Proc. Zoo. Soc. London 1932*, 1932, pp. 595–611) by Maud J. Morris (Mrs. O. W. Richards). This is the first of a proposed series of papers dealing with the factors influencing the fertility of the moths *E. kühniella* Z. and *P. interpunctella* Hb.

In a study of the alimentary canal in *Pieris brassicæ* and the endodermal origin of the Malpighian tubules of insects (*Q.J.M.S.*, **75**, 1932, 283–305), H. Henson interprets the interstitial (imaginal) rings of the insect gut as homologous with the lips of the embryonic mouth and anus of *Peripatus* (*i.e.* the blastopore lips). He thus changes his opinion expressed in 1931, which was based on a morphological study of *Vanessa urticæ*, that they are the persistent embryonic ends of the stomodæum and proctodæum. The influence of temperature and air humidity on the development and mortality of *Pieris brassicæ* have been studied by H. Z. Klein (*Zeits. f. angew. Ent.*, **19**, 1932, 395–448).

One of the results of a study of the sensitivity of the legs of butterflies to sugars by A. L. Anderson (*Jl. Exp. Zool.*, **63**, 1932, 233–59) is that he finds the legs of one of the most sensitive butterflies may be as much as 1,200 times as sensitive to saccharose as the human tongue.

An account of the recent development of melanism in the larvæ of certain species of Lepidoptera has been written by J. W. H. Harrison (*Proc. Roy. Soc. London, B.*, **111**, 1932, 188–200). A. W. McKenny Hughes (*loc. cit.*, *B.*, **110**, 1932, 378–402) has described some experiments which were carried out in an attempt to induce melanism in *Selenia bilunaria* Esper., by feeding the larvæ on hawthorn treated with lead and manganese salts. No melanic individuals, however, appeared in the treated or control broods. Had the insects behaved in the same way as those of J. W. H. Harrison in previous work, some melanics would have appeared.

An important study of voltinism and dormancy has been made by R. W. Dawson (*Jl. Exp. Zool.*, **59**, 1931, 87–131) dealing with the Polyphemus moth.

Hemiptera.—The climbing organ on the distal end of the tibia of the anterior and middle pairs of legs possessed by *Rhodnius prolixus* has been fully described by J. D. Gillett and V. B. Wigglesworth (*Proc. Roy. Soc. London, B.*, **111**, 1932, 364–76).

W. V. King and W. S. Cook (*U.S. Dept. Agric.*, Tech. Bull. 296, 1932, 11 pp.) have made a study of the feeding punctures of Mirids (Capsids) and other plant-sucking insects and their effect on cotton. This was done with a view to ascertaining whether the injury to cotton following the feeding of these insects was the result of a transmissible virus or due to mechanical or chemical injury. The results lead the authors to believe that hopper damage is due to injected substances normally present in the insects and toxic to the plant, rather than to a transmissible disease.

The biological section of a monograph on *Trialeurodes vaporariorum* (Westwood) by H. Weber has appeared (*Z. Morph. Oekol. Tiere*, **23**, 1931, 575–753).

The difficulty of using cultures of aphids for experimentation purposes is emphasised by the results of a study of the differences exhibited by various clones or parthenogenetic lines of *Macrosiphum solanifolii* by A. F. Shull (*Amer. Nat.*, **66**, 1932, 385–409). Differences in the production of winged offspring as well as in colour are described. These characters are also subject to change, as is shown by the description of how one clone suddenly changed in several respects, for example it reversed its response to light and darkness with respect to wing production. R. Kirschner (*Biol. Zbl.*, **52**, 1932, 103–17)

has found that deviation from the normal life-cycle of *Phorodon humuli* was caused in certain cases by chemical change in the food plant due to leaf-roll disease.

W. Carter has made a study of populations of *Pseudococcus brevipes* (Ckl.) occurring on pineapple plants (*Ecology*, **13**, 1932, 296–304).

Hymenoptera.—The biology of the apple sawfly (*Hoplocampa testudinea* Klug.) has been investigated by H. W. Miles (*Ann. App. Biol.*, **19**, 1932, 420–31).

The early stages of five species of Tryphonine Hymenoptera parasitic on sawfly larvæ have been described by C. P. Clausen (*Proc. Ent. Soc. Wash.*, **34**, 1932, 49–60). After studying natural superparasitism by *Collyria calcitrator* Grav., G. Salt (*Bull. Ent. Res.*, **23**, 1932, 211–15) has come to the conclusion that there is a degree of discrimination on the part of the ovipositing females. Previously it had been widely assumed that parasites oviposit in their hosts purely at random, not discriminating between healthy and previously parasitised hosts.

The four larval stages of *Ascogaster carpocapsæ* Viereck, an important Braconid larval parasite of the codling moth and Oriental fruit moth, have been described by J. A. Cox (*N.Y. State Agric. Expt. Sta.*, Tech. Bull. 188, 1932, 26 pp.). The biology and morphology of the Braconid *Chelonus annulipes* Wesm., a parasite of the European corn borer, have been worked out by A. M. Vance (*U.S. Dept. Agric.*, Tech. Bull. 294, 1932, 48 pp.). Another Braconid has also been studied, namely, *Macrocentrus ancylivorus* Roh., a parasite of the Oriental fruit moth, by G. F. Haeussler (*Jl. Agric. Res.*, **45**, 1932, 79–100).

The morphology and biology of *Habrocytus cerealellæ* Ashmead, a Pteromalid parasite of the Angoumois grain moth, has been described by N. S. Noble (*Univ. Calif. Publ. Entom.*, **5**, 1932, 311–54).

An important review article on the biological rôle of heat in the nests of social Hymenoptera has been written by A. Himmer (*Biol. Rev.*, **7**, 1932, 224–53).

T. C. Barnes and H. I. Kohn have made a rather interesting study of the effect of temperature on the leg posture and speed of creeping in the ant *Lasius* (*Biol. Bull.*, **62**, 1932, 306–12). Territory among wood ants, *Formica rufa* L., has formed the subject of a short paper by C. Elton (*Jl. Animal Ecology*, **1**, 1932, 69–76). The first instance of a gynergate, *i.e.* a form exhibiting a gynandromorph-like condition of female and worker characteristics, in ants has been recorded and described by G. S. Tulloch (*Psyche*, **39**, 1932, 48–51). It appears from this that the trophic hypothesis of cast determination may have to be discarded in favour of the blastogenetic hypothesis.

The literature on the nest population in the Vespidæ is

reviewed in an article by Barbara J. Betz (*Qtly. Rev. Biol.*, **7**, 1932, 197–209).

An outline of the work being done by Norma Leveque concerning the evolution and taxonomy of carpenter bees (Xylocopidæ), correlated with a study of their symbiotic mites, has appeared recently (*Ent. Mon. Mag.*, **68**, 1932, 109–12).

Following previous work on contact chemoreceptors in Lepidoptera and Diptera, D. E. Minnich has now (*Jl. Exp. Zool.*, **61**, 1932, 375–93) shown that the first leg and the antenna of the honey bee possess such organs.

Diptera.—A symposium given before the Entomological Society of America on bloodsucking and non-bloodsucking flies in relation to human welfare has been reported (*Ann. Ent. Soc. America*, **25**, 1932, 603–30). The contributors were F. C. Bishopp, H. H. Schwardt, E. H. Hinman, W. B. Herms, and E. C. Faust.

E. H. Hinman (*Qtly. Rev. Biol.*, **7**, 1932, 210–17) has reviewed the literature on the utilisation of water colloids and material in solution by aquatic animals with special reference to mosquito larvæ. The same author has reported the presence of bacteria within the eggs of mosquitoes (*Science*, **76**, 1932, 106–7). The importance of the possibility of such an hereditary transmission of the etiological agent of either yellow fever or dengue can be readily understood. G. H. Bradley (*Jl. Agric. Res.*, **44**, 1932, 381–99) has made a study of some factors associated with the breeding of *Anopheles* mosquitoes. P. Tate and M. Vincent (*Nature*, **130**, 1932, 366–7) have recorded that, while only 30 per cent. of their *Culex pipiens* gorged when kept in the dark, after exposure to light 66–90 per cent. gorged.

H. F. Barnes (*Proc. Zool. Soc. London 1932*, 1932, 323–34) has shown that food affects the size of adult midges and in addition the number of antennal segments in some species and genera of Cecidomyidæ. The infestation of wheat by the wheat blossom gall midges has been studied over a period of five years by the same author (*Jl. Animal Ecology*, **1**, 1932, 12–31). This is the first of a series of similar studies on fluctuations in insect populations in the field.

J. S. Steward has written a note on *Simulium* sp. attacking horses and cattle in Herefordshire (*Rept. Director, Univ. Cambridge, Instit. Animal Pathology*, 2(*1931*), 1932, 194–7). This is rather an unusual occurrence in Great Britain.

The oviposition stimuli of the burr-seed fly, *Euaresta æqualis* Loew (Trypetidæ) have been studied by G. A. Currie (*Bull. Ent. Res.*, **23**, 1932, 191–3). Four successive stimuli apparently are necessary for oviposition, namely: the characteristic odour of its host; a body of size and shape of the same order of magnitude as the "cockle" burrs; a spiny surface

which gives the immediate local stimulus to dip the ovipositor and penetrate the burr, and hooks on the spines to give the flies a good foothold for purchase in penetrating the capsule; and finally the right texture of the capsule.

Egg production in *Drosophila melanogaster* and some factors which influence it are discussed by W. W. Alpatov (*Jl. Exp. Zool.*, **63**, 1932, 85–111). It is suggested that a thorough study of egg production might throw light on problems of mass appearance of injurious insects. R. Pearl (*loc. cit.*, **63**, 1932, 57–84) has made a study of the effect of density of population on egg production. As the density of population within a closed bottle increases, the daily rate of egg production per female of *Drosophila* decreases. The orderly change in rate of egg production with increasing density is shown to be described by the same type of mathematical equation as that which relates the mean free path of molecules to density in a gas.

Two more studies on the nutrition of blowfly larvæ by R. P. Hobson have appeared. The first (*Jl. Exp. Biol.*, **9**, 1932, 359–65) deals with the liquefaction of muscle, and it is suggested that the chief factors involved are mechanical maceration and the alkaline reaction which results in the first place from bacterial action. The second (*loc. cit.*, 366–77) treats of the normal rôle of micro-organisms in larval growth. This paper indicates that the chief function of micro-organisms is to supply accessory food substances which are partly deficient in muscle. The growth factor involved does not appear to be identical with vitamin B_1 or B_2. O. R. Causey (*Amer. Jl. Hygiene*, **15**, 1932, 276–86) deals with sterilisation and growth of the eggs and larvæ of the blowfly. A. C. Evans (*Jl. Exp. Biol.*, **9**, 1932, 314–21) has investigated some aspects of chemical changes during insect metamorphosis, using *Lucilia sericata*. The changes in proteins and degradation products, skeletal or chitin-N, total carbohydrate and fatty acids, were studied at frequent intervals during the change from larva to adult.

G. Salt in an account of a year's work on the natural control of *Lucilia sericata* (*Bull. Ent. Res.*, **23**, 1932, 235–45) has expressed the opinion that the reproductive rate of this fly is of such a nature as to preclude the method of biological control. An important advance seems likely to have been achieved in the attempts that are being made to discover an artificial bait for the sheep blowfly in Australia. M. R. Freney (*Australian Jl. Council Sci. and Ind. Res.*, **5**, 1932, 28–30 and 94–7) has shown that keratin from wool fibre decomposed by sodium sulphide solution is more attractive to primary than to secondary blowflies. There are also notes by Mary E. Fuller (*loc. cit.*, 162–4) on the effects of carcass burial. The latter worker has

figured and described the larvæ of Australian sheep blowflies (*Proc. Linn. Soc. N.S.W.*, **57**, 1932, 77–91).

R. T. Webber (*Jl. Agric. Res.*, **45**, 1932, 193–208) has written a full account of *Sturmia inconspicua* Meig., a Tachinid parasite of the gipsy moth. A. E. Cameron (*Parasitology*, **24**, 1932, 185–95) has described the adult and the early third-stage larva of the nasal bot fly, *Cephenomyia auribarbis* Meig., of the red deer.

Other Orders.—A preliminary account of the Protura of Australia has been given by H. Womersley (*Proc. Linn. Soc. N.S.W.*, **57**, 1932, 69–76).

The second part of D. S. Maclagan's ecological study of *Sminthurus viridis* Linn. has now been published (*Bull. Ent. Res.*, **23**, 1932, 151–90). This includes the seasonal and geographical variation in abundance, applied control and remedial measures, and general conclusions under three sub-headings—economic, ecological, and evolutionary considerations. An account of experiments with soil factors affecting oviposition of *Sminthurus viridis* as well as the technique used is given by J. Davidson (*Australia Jl. Exp. Biol. and Med. Sci.*, **10**, 1932, 1–16). Another paper by the same author on the viability of the eggs of this insect in relation to their environment has also appeared (*loc. cit.*, 65–88). The anatomy, in particular that of the digestive system and the cephalic glands, of a new Collembolan has been described by D. Mukerji (*Rec. Ind. Mus.*, **34**, 1932, 47–79).

J. V. Pearman (*Ent. Mon. Mag.*, **68**, 1932, 193–204) has given notes on the genus *Psocus* with special reference to the British species.

The position of Chrysopids as a factor in the natural control of the Oriental fruit moth has been studied by W. L. Putman (*Canad. Ent.*, **64**, 1932, 121–6) and he has found that they are important.

H. S. Leeson (*Parasitology*, **24**, 1932, 196–209) has investigated the effect of temperature and humidity upon the survival of certain unfed rat fleas. The methods used to eliminate errors in technique are described. One of the results is the conclusion that high temperatures and low humidities tend to shorten life; and conversely low temperatures and high humidities tend to produce longer lives.

ARTICLES

BINAURAL SOUND-LOCATORS[1]

By E. T. PARIS, D.Sc., F.Inst.P.

The instruments known as binaural sound-locators have been developed in Anti-Aircraft Defence for finding the direction of aircraft at night by sound. The development of such locators began about the year 1917 when the dropping of bombs from aircraft at night had become a regular feature of warfare.

The problem of anti-aircraft sound-location may be divided into two parts, the first being the determination of the direction from which sound-waves from an aircraft arrive at some point on the earth's surface. This direction may conveniently be called the " line of sound " to the aircraft. Since sound-waves travel in air at about 1,100 ft./sec., while the speed of bombing aeroplanes is generally between 150 and 250 ft./sec., the " line of sound "—if we ignore refraction effects due to wind and temperature-variations in the atmosphere—is always the direction to some past position of the aircraft. Also this past position is at a considerable distance from the position occupied by the aeroplane at the time it emitted the sound received by the sound-locator. For example, the average time taken by sound to travel to a sound-locator from an aeroplane at 10,000 ft. is about 15 seconds and during this time the aeroplane moves along its course for a distance of about half a mile. Thus the " line of sound " is a line from the sound-locator to a point half a mile behind the aeroplane. The second part of the problem of sound-location is therefore the deduction of the present line of sight from a past line of sight. This " prediction " from the past into the present can be accomplished if the course of the aircraft and its speed along the course are known. The process of finding the present line of sight is called colloquially " correcting for the lag of sound." We shall in this article be concerned mainly with the design of sound-locators for finding the line of sound, but some mention

[1] Much of the information concerning sound-locators in this article has come to me through official channels, and I am indebted to the Royal Engineer Board for permission to publish it and to reproduce the photographs in Figs. 3 and 4.—E. T. P.

will be made of the principles on which devices for applying the lag-of-sound correction can be designed.

The design of sound-locators for anti-aircraft defence began in this country in the Anti-Aircraft Experimental Section of the Munitions Inventions Department. This Department was a war-time organisation and is, of course, now defunct. Simultaneously experiments were also carried on at the National Physical Laboratory. It was in the A.A. Experimental Section, under the direction of Prof. A. V. Hill, that the design for the first binaural sound-locator used in the British Army was produced. At the time when experimental work was begun, there was a binaural apparatus in the French Army known as the Claude " orthophone," and tests were made with one of these instruments. The orthophone was intended for the location of guns and machine-guns by sound and, although it appears never to have attained much success when used for the purpose for which it was designed, it seems to have provided the starting-point for the development of a binaural locator for use in anti-aircraft defence.

The Claude apparatus was the simplest type of binaural sound-locator that could be devised. It was designed to make use of the natural binaural faculty of a listener, that is, the faculty which enables him to determine whether a sound is coming from left or right or straight ahead. This faculty is dependent on the simultaneous employment of both ears, and the sensations experienced are probably due to an appreciation of a difference in the time of arrival of a sound at the right and left ears. If sound from a certain source reaches the right ear of a listener before it reaches his left ear then he judges the source to lie to the right, and conversely if the sound reaches his left ear first he judges the source to be to the left. If the sound reaches both ears simultaneously then the source of sound appears to be straight ahead. Since the distance from ear to ear round the back of the head is only about six inches, and since sound travels this distance in about one two-thousandth of a second, the time-differences which give rise to the binaural sensation of direction must be very small. The idea underlying the Claude apparatus was that if there were a virtual extension of the distance between the ears, such as can be secured by the use of two listening tubes leading from two points some distance apart, one to the right and one to the left ear, it should be possible, by a rotation of a stand carrying the tubes, to make accurate determinations of the angular bearings of sources of sound, because, if a suitable distance between the open ends of the two tubes is chosen, a small angular rotation of the stand would produce an easily apprehended time-difference at the ears of the listener.

The Claude apparatus took the form shown diagrammatically in Fig. 1. There were two horizontal metal tubes T_1 and T_2, bent into the shape shown in the figure. The sound was picked up through the open ends at O_1 and O_2, these being bent forward for a short distance towards the direction from which the sound arrived. The tubes were continued downwards alongside a vertical shaft X, and to their other extremities, at t_1 and t_2 in Fig. 1, was attached a stethoscope head-fitting, so that the sound entering at O_2 was led to the right ear of the listener while that entering at O_1 was led to his left ear. The tubes T_1 and T_2 could be rotated in a horizontal plane about the vertical axis X by means of the hand-control h until the sound that was being located appeared to the listener to be straight ahead. When this happened the line of sound was at right angles to a line joining O_1 and O_2 and the bearing could be read on a scale with which the instrument was provided. The whole instrument was designed to be supported in the roof of a dug-out from the inside of which the listener made his observations.

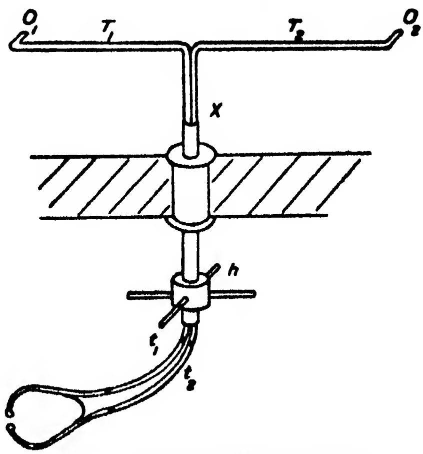

FIG. 1.—The Claude Orthophone.

With the help of this instrument the azimuthal bearing of a source of sound could be found. To define the direction of an aircraft from a point on the earth's surface it is, however, necessary to determine a second angular co-ordinate. Thus, in the binaural sound-locator as finally developed there were two listeners, one of whom found the azimuthal bearing by the rotation of a horizontal cross-arm about a vertical axis as in the Claude orthophone, while the other found the elevation in a vertical plane. The second, or elevation, listener rotated an arm in a vertical plane about the horizontal axis provided by the cross-arm operated by the azimuthal listener. This method of building a sound-locator is the altazimuth method and is shown diagrammatically in Fig. 2. The vertical axis is X and A_1, A_2 are the two points where the sound heard by the azimuth listener is picked up. The cross-arm A_1 A_2 is horizontal and can be rotated about its point of support at O. The sound heard by the elevation listener is picked up at E_1 and E_2 and the arm E_1 E_2 can be rotated about A_1 in a vertical plane. When both listeners are " on sound " all four points A_1, A_2,

E_1 and E_2 lie in a plane the normal to which is the line of sound.

For aircraft location it is found insufficient to employ only the open ends of tubes for picking up the sound, and sound-collectors are mounted with their centres at A_1, A_2, E_1, E_2. In some sound-locators these collectors are conical trumpets with tubes leading back from the narrow ends of the cones to the stethoscope worn by the listeners. The cones act in the same way as the ordinary ear-trumpet and serve to magnify faint sounds and make them easily audible to the listener; they also assist a listener to concentrate his attention on the sound coming from one direction by screening off sounds coming from other directions.

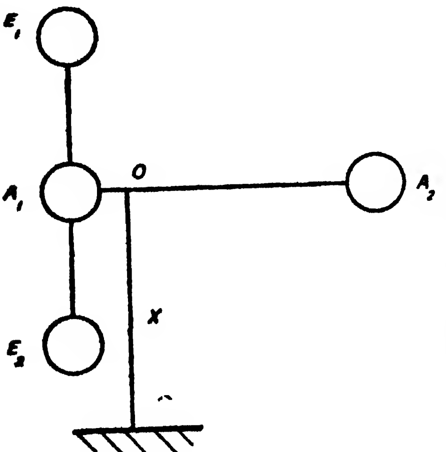

FIG. 2.—Altazimuth Sound-Locator Mounting.

A sound-locator with four conical trumpets on an altazimuth stand is shown in the photograph reproduced in Fig. 3. The trumpets, which are made of thin metal, are encased in pyramidal wooden sheaths of square cross-section, and there is an air-space between the wooden sheaths and the cone. This construction is intended to prevent the incidence of sound on the walls of the cone and to minimise the disturbing effect of sounds coming from lateral directions (*e.g.* the sound of road traffic).

We may now enquire into the accuracy with which the direction of a source of sound can be found by listeners using a sound locator. In discussing this question we shall ignore effects due to the refraction of sound in the atmosphere. Both the temperature lapse-rate in the atmosphere and the variation of wind strength and direction with height above the earth's surface refract the rays of sound from an aircraft, so that even when the lag of sound has been corrected for, the line of sound does not in general coincide with a past line of sight. These refraction effects are calculable by methods that have been described [1] and will not be considered here. When they are left out of account, there remains the question as to the accuracy with which a locator can be used to determine the normal to the wave-fronts arriving at the point of observation. It is

[1] E. A. Milne, *Phil. Mag.*, vol. XLII, p. 100 (1921).

necessary as a preliminary to consider the nature of binaural hearing.

As stated above, the binaural sensation of direction is probably due to a difference in the time of arrival of sound-waves at the two ears. At one time, however, it appears to have been held that the perception of direction was attributable to a difference in the amplitude of the vibrations affecting the two ears, this difference being caused by the sound-shadow thrown by the listener's head. It was shown by Rayleigh[1] that this hypothesis did not adequately explain the phenomena of binaural hearing. For example, the head-shadow formed by sound-waves of frequency 128 cycles per second produced a barely perceptible difference in amplitude at the two ears, but the perception of direction was as clear as at higher frequencies, when the head-shadow was more definite. Rayleigh's hypothesis was that up to frequencies of 512 cycles per second, and perhaps higher, a phase-difference between the sound occurring at the two ears could be recognised and that a listener's judgment of the direction of a sound was founded on an appreciation of this phase-difference. The emphasis laid by Rayleigh on phase-difference as distinct from differences in amplitude or intensity, led to the belief that his hypothesis implied that the apparent direction of a source emitting a continuous tone was determined only by the phase-difference (measured as an angle or as a fraction of a period) between the vibrations stimulating the two ears, and not by the time-difference to which the phase-difference corresponded. It is difficult to believe that any such implication was intended ; there would be obvious difficulties in the case of complex sounds, for the various component tones would be associated with different apparent directions. Also a source of varying frequency would appear to be continually changing its direction. Hornbostel and Wertheimer,[2] in 1920, advocated the view that time-difference was the determining factor in localisation, and in a recent publication Shaxby and Gage[3] describe experiments which appear to show definitely that a given localisation can be associated with a certain time-difference. Shaxby and Gage conclude from their experiments that " for ordinary sounds, at any rate for frequencies lower than about 1,200 vibrations per second, the physical phenomenon on which localisation in the median plane depends is the interval of time elapsing between the arrival of the sound-waves at the two ears."

[1] *Phil. Mag.*, vol. XIII, pp. 214–32 (1907) ; *Sci. Papers*, vol. V, pp. 347–63.

[2] *Sitzungber. Preuss. Akad. d. Wissensch.*, vol. XX, pp. 388–96 (1920) ; see also Hornbostel, *Phys. Soc. Discussion on Audition*, p. 120 (1931).

[3] *Studies in the Localisation of Sound*, by J. H. Shaxby and F. H. Gage, *Med. Res. Council Special Report Series*, No. 166 (1932).

It appears, therefore, that, except in the case of sound of high frequency, current opinion favours time-difference as a principal factor in binaural localisation in everyday life. What is more important, however, is that it has been demonstrated that time-difference alone provides a sufficient basis for a judgment of localisation. That time-difference alone is sufficient can be confirmed by the use of an apparatus designed by G. W. Stewart [1] and called a "Phaser." This apparatus is so made that alternating currents of the same frequency and amplitude pass through two telephone receivers on the ears of a listener. The relative phase of the currents can be altered at will and it is found that a binaural sensation of direction is experienced by the listener, and that when the phase is changing he is conscious of a moving "sound-image." Since in any particular experiment with the phaser the frequency of the sound remains constant, every phase-difference corresponds to a definite time-difference. With this apparatus there is no variation in the amplitude or quality of the sounds at the two ears and therefore localisation is due to time-difference alone.

In a sound-locator such as the Claude orthophone the listener finds direction solely by time-difference, for this is the only thing that changes as the instrument is rotated. Owing to the small size of the openings through which the sound enters the apparatus there can be no change either in the amplitude or in the quality of the sound reaching the listener's ears. It is true that, except when the listener localises the sound in the median plane, one of the openings will be farther from the source than the other and that there is theoretically a difference in amplitude on this account; but in practice, unless the source is very near the locator, the difference is quite negligible. Let the locator be initially placed so that the openings O_1 and O_2 (Fig. 1) are equidistant from the source of sound, and then let the stand be rotated through an angle α. If L is the length of each arm of the locator, and a cm./sec. is the velocity of sound in air, the time-difference consequent on the rotation is $(2L \sin \alpha)/a$ seconds, or for small values of α approximately $2L\alpha/a$ seconds. If Δt is the smallest time-difference that can be appreciated with certainty by a normal listener and we write $\lambda = a.\Delta t$ then the greatest angular error that would be made in laying the locator is given by $\sin \alpha = \lambda/2L$, or $\alpha = \lambda/2L$ radians approximately. The distance $2L$ is called the base-length of the locator and we see that the accuracy of laying should be inversely proportional to the base-length. According to the experiments of Hornbostel and Wertheimer (*loc. cit.*) the value of λ is about 1 cm., so that even with base-

[1] *Phys. Rev.*, vol. XV, p. 433 (1920).

FIG. 3.—A FOUR-TRUMPET SOUND-LOCATOR.

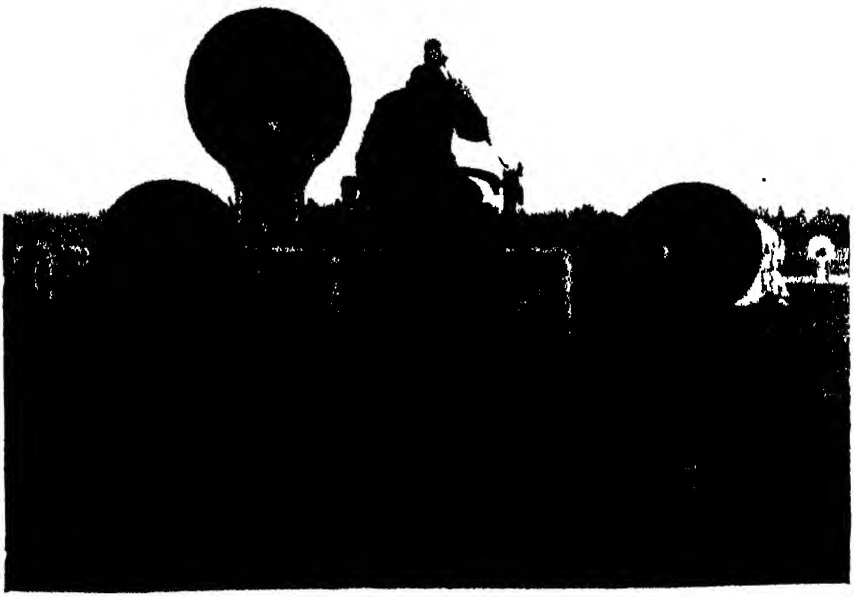

FIG. 4.—THE GOERZ SOUND-LOCATOR.

lengths of quite moderate dimensions, say L = 1 metre, the greatest error should not be more than 1/200 the radian, or between a quarter and a half of a degree.

In a sound-locator such as that shown in Fig. 3, in which the sound is received by conical trumpets, the principal effect on which localisation depends is still probably time-difference. The use of sound-collectors is, however, accompanied by other effects which may be of assistance to the listeners. These other effects are associated with the directional properties of the sound-collectors. Conical trumpets have different polar curves of reception for sounds of different frequencies, but in all cases the received sound is a maximum when the axis of the cone is pointing towards the source. When the axis of the cone is moved away from the direction to the source, the loudness of the received sound falls off and the higher the frequency of the sound the more marked is the falling off for a given angular movement. It follows from this that, in addition to time-difference two other effects occur which may be of help to listeners. Firstly, the sound is loudest when the trumpets point towards the source. In the construction shown in Fig. 3, the trumpet mouths are coplanar and are arranged to lie in the plane of the wave-fronts of the received sound when the time-difference is zero, and hence zero time-difference and maximum loudness occur together. Secondly, if, as is the case with aircraft, the sound to be located is very complex, there is a change of quality as the sound-locator is moved round through different angles from the direction to the source.

It is not possible to say what parts are played by these loudness and quality changes or even whether or not they are important in comparison with time-difference. It may be significant, however, that most users of sound-locators agree that they find localisation easiest when they can hear the high-pitched sibilant constituents of aeroplane sound. The frequencies of these constituents are very high, far above those for which the time-difference theory has been found to be satisfactory. On the other hand, it must be remembered that the sound from aircraft suffers considerable and rapid variation in amplitude (due to meteorological hazards) and it is conceivable that there may be some mechanism of hearing whereby localisation can be made by an appreciation of the time-difference between the arrival at the ears of the beginnings (or ends) of trains of waves of different amplitude.

The base-length in the locator shown in Fig. 3 is 54 inches. On the assumption that localisations are made entirely by time-difference and that the minimum perceptible path-difference is 1 cm., the determination of direction (on a fixed source) should be possible to within one degree. This is about the

accuracy that can be obtained if trained listeners are used. The accuracy on a moving source is of course not so good.

The selection of listeners for sound-locators is a matter of great importance if accurate results are to be obtained. It has been customary to test the binaural powers of individuals by observing the accuracy with which they can lay a sound-locator, in azimuth only, on a fixed source of sound. It was discovered, in the early days of sound-location, that certain listeners would lay the locator very consistently but that the mean of the directions found would not coincide with the theoretical direction, *i.e.* the direction which would make the length of path of the sound to both ears equal. This deviation from the theoretical direction was called the "personal error" of the listener and sometimes amounted to as much as one degree with a locator having a base-length of

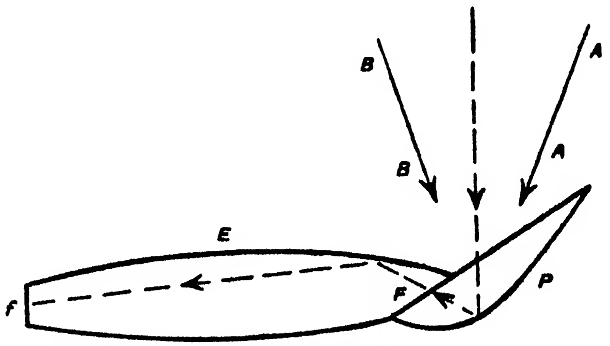

FIG. 5.—Goerz Paraboloid-Ellipsoid Combination.

about five feet. The corresponding path-difference is about 2·5 cm., and is considerably greater than the minimum path-difference which the listener could detect. Shaxby and Gage (*loc. cit. supra*), using a laboratory method, have recorded the personal errors of a number of observers. In an examination of forty individuals they found that (expressed as path-differences) the personal error varied from 0·02 cm. to 5·03 cm. (about equally distributed right and left), the average being about 1·2 cm. At the same time they recorded the scatter of the listeners' observations and found that it might happen that an observer with a large personal error had a small scatter, or *vice versa*. They use the convenient terms "bias" and "uncertainty" to define the quality of a listener. The "bias" is the personal error of the listener expressed as path-difference, and the "uncertainty" is the standard deviation of his observations. A good listener must have a small bias as well as a small uncertainty.

In recent years a sound locator has been manufactured by

the firm of K. P. Goerz in Bratislava, Czechoslovakia, which presents novel features in the design and arrangement of the sound-collectors. A view of the instrument is reproduced in Fig. 4; a detailed description of it, including theoretical considerations, has been given by C. v. Hofe.[1] The sound collecting units are paraboloid-ellipsoid combinations, and one of them is shown in section in Fig. 5. The sound is received first of all on the paraboloidal reflector P, which brings the rays to a focus at F. From this focus the sound is led to the listener's ear by the elongated hollow ellipsoid E. The theory is that the rays of sound after passing through the focus F, which is also one of the focal points of the ellipsoid, will be reflected once more from the inner surface of the wall of the ellipsoid and again brought to a focus at *f*. The end of the ellipsoid near *f* is cut off and a porous rubber ring attached to the circular opening. This ring fits over the listener's ear, and when the ear is held in place the entrance to the meatus is approximately at the focus *f*. The rays incident on the paraboloidal reflector can of course only be brought to a focus when they are parallel to the axis of the paraboloid. The paraboloid and the entrance to the ellipsoid are shaped in such a way that when rays are incident from the right (looking forward towards the source), as from AA in Fig. 5, more sound enters the ellipsoid than when the rays come from the left as from BB in Fig. 5. In this way a differential intensity effect is obtained, the sound being louder on the side to which the source lies.

The azimuth listener uses two sound-collecting units similar to that shown in Fig. 5. For the elevation listener the elongated ellipsoid is divided at its widest part and the two halves set at right angles with a "flat-elbow" joint. The arrangement is shown in Fig. 6. It will be noticed that although the arrangement of the sound-collectors is such that one listener finds the azimuth angle and the other finds the elevation, the stand is not of the altazimuth type shown in Fig. 2, but a variation of it in which the elevation collectors are "staggered." The elevation and azimuth parts of the locator are mounted on opposite sides of a tripod stand with a large round top on which is a seat for the operator of a mechanism

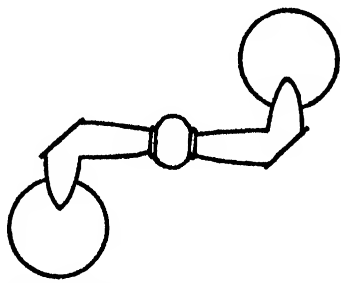

FIG. 6.—Arrangement of Elevator Sound-collectors in Goerz Locator.

[1] *Zeitschr. f. Instrumentenkunde*, vol. XLIX, p. 331 (1929); other descriptions of the locator and accessory apparatus are contained in various articles which have appeared in the *Rivista di Artiglieria e Genio* from 1928 to 1931.

for applying the lag of sound correction. The azimuth and elevation collectors are linked mechanically in such a way that the axes of all four paraboloidal reflectors are always parallel to one another.

The instrument is interesting because it is designed to produce a difference in amplitude at the two ears of the listener, and the intention of the designers is that the listener should locate the sound by rotating the instrument until the sound appears equally loud in both ears. At first sight it seems improbable that a "ray" construction could give any useful results when applied to the reflexion of sound in the paraboloid-ellipsoid combination, since the dimensions of the reflecting

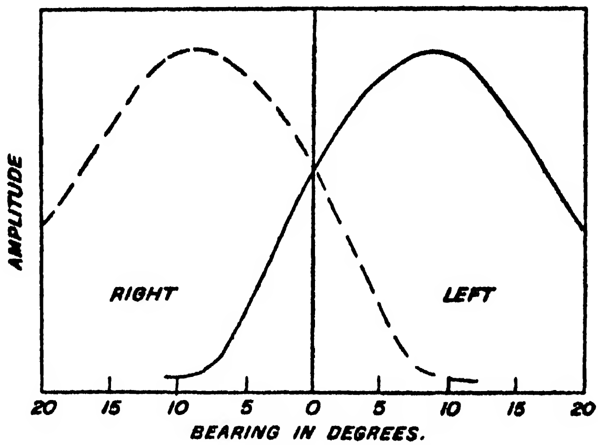

FIG. 7.—Differential Sound-amplitude Effect in Goerz Locator (Frequency 1,000 cycles).

surfaces are comparable with the wavelength. Experiments show, however, that quite well-marked differences in amplitude can be produced at the listeners' ears. The curves in Fig. 7, for example, show the variation in amplitude for sound of 1,000 cycles per second as the listening unit is rotated. The curves were obtained by placing a condenser microphone at the end of one of the azimuth ellipsoids in the position that would be occupied by one of the listener's ears. The source of sound was a loud-speaker emitting a steady and fairly pure tone of 1,000 cycles per second at some distance from the locator. The response of the microphone is proportional to the amplitude of the vibration affecting the diaphragm and this was plotted against the angular bearing of the locator. The full curve shows the amplitude of the sound affecting the right ear and the broken curve the amplitude that would simultaneously affect the left ear. When the bearing is 0° the amplitude at

the two ears is of course equal. If the instrument is moved to the left the amplitude at the right ear increases and that at the left ear decreases until when the bearing is about 5° from the central position the amplitude at the right ear is about twice that at the left ear. This corresponds to a difference of 6 decibels between the stimuli at the two ears and the difference in loudness would be easily perceived. In this locator the listener has three aids for localising the sound in the median plane; these are (i) the usual time-difference effect, (ii) a differential loudness effect—which will obviously be more apparent in the high-frequency components of the sound, and (iii) a differential quality effect.

There are, as pointed out above, loudness and quality effects in the sound-locator with conical trumpets shown in Fig. 3, but they are the same for both ears. The point about the Goerz locator is that unless the instrument is placed so that the sound appears to be directly ahead, the loudness and quality of the sounds heard by the two ears will be different.

Two other types of sound-locator may be mentioned. These are the Exponential Sound-Locator [1] of American origin and the French Telesitemetre.[2] The former is equipped with four large exponential trumpets (each about 15 feet long) as sound-collectors, two being used for finding the azimuth angle and two for elevation. The locator is the same in principle as the four-trumpet locator shown in Fig. 3, but the base-length is greater, being in the neighbourhood of 9 feet. The Telesitemetre is also a large locator with four sound-collectors of a type designed by Prof. J. Perrin of Paris. They are nests of small conical trumpets (forty-two trumpets to each collector) and are called "myriaphones."

The locators described and mentioned above include the principal types at present made. With the exception of the Goerz locator, they rely ostensibly on the perception of time-difference by the listeners. In the present state of our knowledge it is not possible to say whether time-difference is the only factor of importance, or what are the advantages—if any—of the Goerz method of introducing loudness differences. Nor is it known what part is played by changes in quality. The experiments already mentioned demonstrate that localisation can be made from time-differences; they do not demonstrate that time-difference is the only factor relied on in the

[1] The exponential locator is made by the Sperry Gyroscope Co. Photographs have appeared recently in the daily press. There is a description and a good photograph in the *Coast Artillery Journal* for November–December 1931. See also P. R. Bassett, *Coast Artillery Journal*, **75**, 200 (May–June 1932).

[2] A photograph of the telesitemetre has appeared in the *Illustrated London News* and is reproduced in the *Scientific American* for December 1930.

use of sound-locators and in everyday life. It is, in fact, probable that localisation in everyday life is made largely by means of extra-auditory clues. An admirable account of the factors affecting binaural localisation with some reference to the possible effect of depriving a listener of extra-auditory clues has recently been given by H. Banister.[1] It seems possible that although a sound-locator can be made with time-difference alone as a basis, yet better results may be obtained when additional clues, such as those provided by differences in loudness and quality, are presented to the listener.

It was remarked at the beginning of this article that the second part of the problem of sound-location was the deduction of the present line of sight to an aircraft from observations on the line of sound. This is a relatively simple problem if acoustical refraction effects are ignored and the track of the aircraft is supposed to be straight and at constant height. The line of sound at any instant is of course a past line of sight and all past lines of sight will be in a plane which is, in fact, the plane containing the track of the aircraft and the point of observation. Thus in Fig. 8 let O be the position of the sound-locator and OT_1 OT_2 two successive lines of sound. The triangle OT_1T_2 lies in the plane containing track and point of observation and the intersection of this plane with a horizontal plane gives the course of the aircraft. Let t seconds be the time taken by the sound to travel from T_2 to O, then $OT_2 = at$, and if v is the velocity of the aircraft along its track its position at the instant the sound is received at O is at T_3 such that $T_2T_3 = vt$, so that $T_2T_3/OT_2 = v/a$. Since the directions of OT_2 and T_2T_3 are known, the direction of the line of sight OT_3 can be determined, if v is known. In practice it is usual to rely on an estimated or guessed value for v.

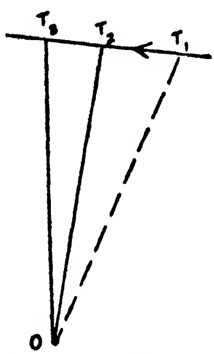

FIG. 8.—Deduction of Line of Sight from Line of Sound.

A very elegant and simple device for applying the lag-of-sound correction to a sound-locator was designed in the A.A. Experimental Section. The device was called a "ringsight" and the theory of its working can be explained by reference to Fig. 9. Let O represent the position of the sound-locator and let T_1 be some point on the line of sound to the aircraft. Let the length of OT_1 be l and with centre T_1 draw a circle of radius r in a horizontal plane and let $r/l = v/a$. Then the line of sight from O to the aircraft will always pass through some

[1] "The Basis of Sound-Localisation," *Phys. Soc. Discussion on Audition*, p. 104 (1931).

point on the ring. Also as the aircraft moves along its track the ring as a whole will move on a parallel course and it is easily seen that the line of sight to the aircraft will be from O through a point on the front edge of the aircraft, judged from the direction in which the ring is moving. The ringsight itself consisted of a bead backsight and a ring foresight, the latter balanced horizontally by means of small weights. The whole sight was mounted rigidly on the sound-locator stand in such a way that the line from the backsight to the centre of the ring was always parallel to the line of sound found by the locator. The ringsight can be seen on the locator shown in Fig. 3. An observer looks at the ring over the backsight and notices the direction in which the ring moves as the locator follows the aircraft; he then selects the leading edge of the ring and a line from the backsight to the leading edge gives him the line of sight to the aircraft. The ratio r/l can be varied, to correspond with different estimated values of v, by increasing or decreasing the distance from the backsight to the centre of the ring.

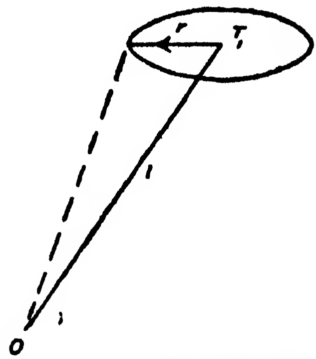

FIG. 9.—Theory of the Ring-sight.

It is curious that the development of sound-locators appears to have taken place solely for military purposes. In view of the difficulty of navigating ships in fog (even with the assistance obtainable from wireless) it might reasonably have been expected that some development of the sound-locator for navigational purposes might have occurred. Perhaps the lack of confidence, frequently expressed by mariners, in the directions found by sound in fog may be partly responsible. For example, a writer in a recent number of the *Nautical Magazine* (February 1932) says that "one of the great nerve-straining things about fog and the signals given by ships is that it is almost impossible to tell from what point of the compass a sound is coming." But another writer in the same number of this periodical describes how ships were habitually navigated up narrow water-ways by timing the echoes of the ship's fog-siren from the left and right banks of the channel. So that there seem to be at least two opinions on the value of directions found by sound in fog. It is difficult to believe that a properly designed sound-locator would fail to give accurately the directions of sound-signals in fog.

THE NATURAL DECOMPOSITION OF PLANT MATERIALS

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CONTENTS

I. INTRODUCTION

NATURAL decomposition is essentially a microbiological process, and one which, when occurring in soil, may profoundly affect its fertility. The micro-organic population of the soil is a complicated and competitive society of many individuals separable both morphologically and functionally into several fairly well defined groups. The balance between the groups and between the individuals of each group is determined by the supply of nutrients and the prevailing environmental conditions. It is true that the somewhat unsatisfactory counting methods employed at present demonstrate that the members of organisms of different groups fluctuate in an astounding and apparently quite capricious way from day to day, and even from hour to hour, but in this connection it must be remembered that plate counts and metabolic activity in the soil are not wholly synonymous. The sum total of the activities of all these groups, or better, the " biological balance " of the whole, is not a wildly fluctuating expression, but one whose change is gradual. Indeed, the direction of the change may be foretold if certain conditioning factors are known. Furthermore, the biological balance largely determines soil fertility, for, in so far as substances of nutritional importance to the plant are concerned, fertility depends not on gross quantity but on availability.

It is chiefly in the case of that paramount element, nitrogen, that the biological balance manifests itself, for while higher plants are designed to utilise nitrogen as nitrate, and possibly also as ammonia, very many of the soil micro-organisms, on the

other hand, are readily able to utilise organic nitrogen or even prefer it. If the conditions are such that microbial growth is favoured, there may be an almost complete absence of inorganic nitrogen in that soil. The inorganic nitrogen will have been transformed to microbial protein, thereby being temporarily immobilised. As a consequence, a condition of nitrogen starvation for higher plants may result. In the competition for nitrogen, it would appear therefore as though the scales were loaded on the side of the micro-organic population of the soil. Though this is undeniably the case, the normal soil conditions of arable land are such that the nitrogen is not held permanently by micro-organisms, but liberated progressively as nitrate by the process of ammonification and subsequent nitrification, the rate of this liberation being determined by prevailing conditions. It will, however, not commence until there is an excess of nitrogen above the microbial requirements. The decisive factor in determining whether or not the soil nitrogen will appear in an inorganic or plant available form is the supply of energy material for the soil micro-organisms. In other words, the availability and amount of the carbonaceous material in the soil by controlling the microbiological balance determines the quantity of nitrogen utilisable by the plant.

The decomposition of organic material, such as plant and animal residues, in the soil is therefore of vital importance in soil economy, and forms also the katabolic links in the endless chain of carbon transformations in nature. Textbooks on microbiology frequently show very involved and artificial diagrams designed to represent the carbon and nitrogen cycles in nature, but inasmuch as these two are commonly treated in separate chapters, the absolute interdependence of them is insufficiently stressed or even overlooked. This review deals mainly with the fundamental chemical aspects of these related processes, the assimilation of carbonaceous material in the decomposition of plant materials, and the accompanying immobilisation of nitrogen. The work described has been carried out largely outside of the soil, though employing soil organisms both as a general soil flora, and in pure culture. There is no reason to suppose that the route of such processes outside the soil is different from those obtaining within it, though the rate is undoubtedly affected, and in general increased markedly.

Since the decomposition of plant materials is a microbiological process it is conditioned by precisely the same fundamental factors as are ordinarily described for the growth and development of heterotrophic micro-organisms. Carbohydrate material is necessary as an energy source, nitrogenous material and inorganic salts for structural purposes ; these together with water, oxygen, and a suitable temperature determine the extent

and rate of growth of the organisms, and therefore of the decomposition of the plant tissue.

II. General—the Composition of Mature Plant Materials

Plant tissues are, of course, built up of a number of constituents which are found to vary considerably in availability to micro-organisms, and which, in consequence, decompose at very different rates. Furthermore it must not be forgotten that certain constituents, though as individuals fully available to attack and assimilation, may be rendered unavailable either wholly or in part by virtue of their structural position, being rendered inaccessible by a barrier or protective layer of a more resistant constituent. Even if the precise availabilities of each separate plant constituent to a particular microflora were accurately known, absolute prediction of the extent of decomposition of the whole under given conditions would be impossible, because of this unknown and quantitatively indeterminable variable, namely, the structural arrangement of the constituents. Two or more plant materials which give similar analytical figures for the content of various constituents may decompose at widely different rates, and to a very different degree, because of these mechanical differences in structure. On the other hand, it is usual that tissues of similar nature though of different source are constructed in much the same general way, so that comparisons can be made ; the importance of this mechanical factor must therefore not be overstressed.

Decomposition in the case of mature plant materials is neither very obvious nor very appreciable unless the structural constituents of the tissue are attacked. There are four main structural substances common to all plant materials, and together comprise 60 to 90 per cent. of the mature plant. These are cellulose, the hemicelluloses (polyuronides), lignin, and the polysaccharide intimately associated with the cellulose.[1] While there is no need to linger here on the nature of either cellulose or lignin, it may be worth while briefly to consider that class of substances known as hemicelluloses, and also the nature of the polysaccharide associated with the cellulose.

The hemicelluloses are polysaccharides built up of mixed monose units, in contrast to such substances as starch or cellulose, which contain but one basal monosaccharide. The units usually found in hemicelluloses do not of necessity belong to only one series, but may be hexoses, or pentoses, or a member of that class of reducing hexosecarboxylic acids known as " uronic

[1] The name "cellulosan" has recently been suggested for this group—Hawley and Norman (1932).

acids " and represented commonly by glucuronic and galacturonic acids. The hexoses which occur frequently are galactose, glucose, and mannose, and the pentoses are xylose and arabinose. Usually a hexose, a pentose, and a uronic acid are all present, though sometimes only two of these groups may be found. The recognition of the widespread distribution of the uronic acids in this class of substances is a quite recent development, and many of the preparations of " xylans," of " arabans," and " galactoarabans " described in earlier literature have been found on re-examination to contain uronic acid also. The term " polyuronide " has been suggested by Candlin and Schryver (1928) for such polysaccharides containing uronic acids, and it is to be preferred to the older term of hemicellulose due to Schultze (1892), since this is unfortunate in suggesting quite erroneously some close relationship to cellulose. In addition to their structural heterogeneity, the polyuronides appear to vary considerably in composition, and preparations from separate samples of the same plant material often contain quite different amounts of the same constituent units. Furthermore, it should be mentioned that not one but several preparations may usually be obtained from any one source, and that these preparations differ not only in physical properties but also in composition. An example of such a separation may be seen in papers by Preece (1930) and Norris and Preece (1930) on the hemicelluloses of corn cobs and wheat bran. While it is possible accurately to determine the pentose and the uronic constituents, the hexose constituents cannot be so readily estimated. Hydrolysis methods as proposed by some workers are unreliable and erratic if uronic acids are present, because of their instability towards ordinary hydrolysing agents. As a result of these difficulties and those due to the structural variability of the hemicelluloses, their evaluation in any plant material presents serious complications, which have not yet been satisfactorily overcome.

The presence of the polysaccharide associated with the cellulose may be demonstrated by carrying out a cellulose estimation by the chlorination method originally proposed by Cross and Bevan. The resulting product consists of " cellulose " in the rigid chemical sense together with the associated polysaccharide, which, in general, is found to be built up of anhydropentose units. In soft woods and some mature plant materials a hexosan, often mannan, is found. Norman (1929) has shown that in oat and rye straws this polysaccharide is a xylan, and Hampton, Haworth, and Hirst (1929) have proved the same substance to be present in esparto cellulose. In view of the extreme resistance of this xylan to extraction, it seems probable that during development it is laid down in the closest physical

association with the cellulose. Furthermore, the steric similarity between the glucose units as arranged in the cellulose molecule, and the xylose units of the xylan, suggest that this polysaccharide and cellulose may be formed by the same mechanism. Indirect evidence of their similarity in steric arrangement is afforded by the fact that X-ray diagrams from celluloses, which must have contained xylan in various quantities, are not dissimilar from those of pure cotton cellulose, and show no trace of a substance with a different identity period. Actually in decomposition studies there is no particular reason why the associated polysaccharide should be considered apart from the cellulose ; in Cross's and Bevan's interpretation of " cellulose " it would rank as such. It is commonly found that the removal of each occurs in parallel, it being obvious that if the cellulose is unattacked only that small portion of the polysaccharide which is superficial to it can be assimilated. The importance of having a knowledge of the quantity of associated polysaccharide present lies in the determination of the pentose units of the hemicelluloses, which is given only by the difference between the total pentose and the pentose in the Cross and Bevan cellulose preparation, a correction being applied for the uronic acids present (Norman, 1929).

III. Decomposition—the Assimilation of Energy Materials

Hebert (1892) examined the order of decomposition of the various constituents of straw, and found the so-called " vasculose " (lignin) to be the most resistant. Dvorak (1912) pointed out that young plants decompose more readily than mature or senescent plants, and ascribed the difference in rate to the higher content of resistant lignocellulose in the latter. In this connection, however, it should not be forgotten that there are other, and more important, differences, particularly in the amount of the nitrogenous substances present. Christie (1916) studied the decomposition of kelp in the soil and compared it with that of alfalfa and straw, showing that in all cases the " pentosans " suffered a loss of 75 to 80 per cent. Schmidt, Peterson, and Fred (1923) determined the percentage losses of the " pentosans " of corn stalks and rye straw undergoing decomposition in comparable circumstances, and found that while the former lost 50 per cent. in 100 days, the latter lost only 35 per cent. in 300 days. In their work on the decomposition of straw and the production of artificial manure from vegetable materials, Hutchinson and Richards (1921) recognised that available nitrogen is essential and in the case of several materials determined the amount necessary for a satisfactory rot under aerobic

conditions. They went further, however, and in their patent for the making of artificial manure (Adco) (Richards and Hutchinson, 1924) attempted to account for the decomposability of plant materials in terms of the constituent substances. They claimed that materials " which contain an adequate total quantity of carbohydrate (for example, 30 per cent. and upwards) such as starch or pentosans, and preferably not too high a proportion of lignocelluloses," were capable of undergoing satisfactory decomposition. Starkey (1924) investigated the relative rates of decomposition of a number of plant materials, but arrived at the conclusion that nitrogen was not a limiting factor. Waksman *et al* (1926, i, ii, iii) in investigating the origin and nature of the humus material of soils determined the losses of various plant constituents during decomposition and arrived at the conclusion that lignin, being relatively resistant to microbial attack, contributes largely, though not exclusively, to the humus fraction. They showed that both hemicelluloses and cellulose suffered heavy losses. Rege (1927) put forward a theory of decomposition based on analyses of rice straw made at frequent intervals during rotting. He observed a very rapid early loss of " pentosans " (or hemicelluloses, of which, however, he only estimated the pentose units) followed by a heavy loss of cellulose, and confirmed the opinion of Waksman and other workers that lignin is very resistant. He connected these two groups—" pentosans " and lignin—and stated that by determining the content of these in any material it is possible to predict its decomposability. If the ratio of the food or energy factor, as he termed the " pentosans," to the inhibitory factor, lignin, is greater than unity, the material is easily decomposed, or if less than 0·5 it is very resistant. To the " pentosans," therefore, he ascribed a pre-eminent position in determining decomposability. It is curious that in defining the energy factor, this worker should have ignored the very heavy loss of cellulose which is always observed in such decompositions and which is clearly demonstrated by his own results. Waksman and Tenney (1927, i) developed certain methods for the analysis of plant materials and employed these, together with the modifications later published by Waksman and Stevens (1930) in a very detailed investigation of many phases of decomposition. The methods suggested are designated by these workers as " proximate," and in some cases the results obtained by the use of them are decidedly difficult to interpret in terms of any particular plant constituent or group. It is in the case of the two structural constituents, cellulose and the hemicelluloses, that their methods are the least satisfactory. The theoretical objections to them have recently been given by Hawley and Norman (1932). Nevertheless, the figures obtained,

if not absolute, are of comparative value, and from them many important conclusions have been drawn. Waksman studied the decomposition of many types of materials, both aerobically and anaerobically and has investigated the nature and formation of peats. The following citations include the more important of the papers by Waksman and his co-workers on these subjects: Waksman and Tenney (1927, ii) (1928), Tenney and Waksman (1929) (1930), Waksman (1931), Waksman and Gerretsen (1931); while in addition this worker has been responsible for a number of summary articles in various journals, which need not be mentioned here.

In the work to be discussed herein, attention was directed mainly to the four chief structural constituents of plant materials. The theory of decomposition proposed by Rege (1927) was re-examined, with the result that the "pentosans" were deposed from the position of importance in which he had placed them. It was necessary first to develop a method for the precise evaluation of the pentose and uronic groups of the hemicelluloses, since, owing to their heterogeneity, it is difficult accurately to determine the complete molecule. This involved also the estimation of the polysaccharide associated with the cellulose, which itself was obtained by the well-tried chlorination method of Cross and Bevan. This is far more satisfactory in practice than the cuprammonium method proposed for plant materials by Charpentier (1921). Lignin was determined by the 72 per cent. sulphuric acid method of Ost and Wilkening (1910) as modified by Schwalbe (1925). This method is not wholly satisfactory but is in very general use, particularly among wood chemists.

These various analyses were applied, at frequent intervals during decomposition, to a number of materials, particular attention being paid to the rôle of the furfuraldehyde-yielding constituents (pentose and uronic units). The sequence of changes observed to take place under aerobic conditions and by the agency of a mixed-soil flora is indicated diagrammatically in Fig. 1 below, and may be briefly stated as follows. Of the four main structural constituents, the hemicelluloses are the first to be attacked, and these are observed to suffer a heavy loss during the first few days of active decomposition. In the case of straws more than 50 per cent. of the original hemicellulose material may be removed during the first week. Subsequent to this their decomposition is slow but steady, till in material completely rotted only very small quantities of these substances remain. It is doubtful whether such residual traces are fragments of the original, or microbially formed products. The cellulose seems to be decomposed but slowly in the first few days, but the rate of attack becomes more and more rapid

as the initial fermentation of the hemicelluloses slackens. After this point the losses of cellulose account for the major part of the organic matter disappearing. There may be constituents which sustain a greater percentage loss, but nevertheless the actual gross loss of cellulose is by far the greatest, and often amounts to 70 per cent. of the total organic matter removed. The polysaccharide intimately associated with the cellulose (together comprising the Cross and Bevan " cellulose " fraction) is removed slowly and at a fairly constant rate following in a general way that of the cellulose, as might, perhaps, be expected. The remaining structural constituent, lignin, is found to be much more resistant, and in the first few weeks of decomposition

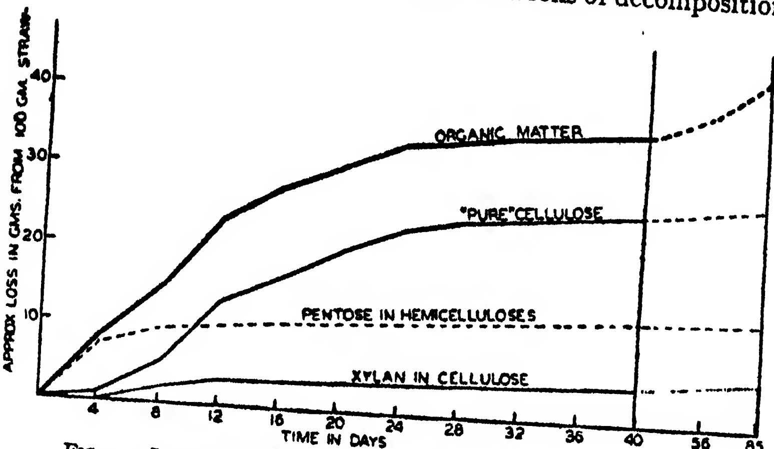

FIG. 1.—Losses of constituents of Oat straw during decomposition.[1]

its loss is very slight. Over a long period a portion of the lignin does appear to be removed, but it is not certain whether this observation is not more apparent than real, for reasons which will be discussed later. Suffice it to say that the lignin is reduced far less than any of the other constituents, and, as a consequence, accumulates as the decomposition proceeds.

Such observations made it clear that the theory of decomposition proposed by Rege (1927) was not based upon a full realisation of the facts, and since the major part of the lost carbonaceous material is accounted for by the cellulose, it is this constituent which is the most important food and energy source for the micro-organisms concerned.

Therefore the hemicelluloses must be deposed from the position of pre-eminent importance which he gave to them, and

[1] The sum of the losses of constituents always amounts to more than the apparent organic matter decomposed, owing to the presence of an appreciable quantity of synthesised microbial tissue.

must be treated on the same plane as the other available constituents, save possibly in the opening stages. Lignin, being relatively unavailable to ordinary soil organisms, forms a physical barrier to their attack, and, as a loose generalisation, plant materials may be said to decompose to an extent which varies inversely with the lignin content. The ratio of available carbonaceous material, *i.e.* hemicelluloses + Cross and Bevan cellulose fraction, to lignin gives a better measure of the probability of decomposition of any material.

The rapid early fermentation of the hemicelluloses which takes place may be ascribed to two causes. Firstly, the hemicelluloses are apparently encrusting substances on the cell wall which would have to be removed in part before the cellulose could suffer any loss. The fact that in extremely far-rotted materials only traces of hemicelluloses can be found provides additional evidence for the view that their distribution in the cell wall is such that, unlike cellulose, they are completely open to attack. Secondly, the hemicelluloses provide a more easily available source of energy than does cellulose, and together with the soluble constituents, such as starches and sugars, pave the way for a general attack on the cellulose by promoting the rapid and active growth of organisms in the early stages. The hemicellulose component of any plant material is far from homogeneous. It is usually possible by physical means to separate several fractions, containing even different sugar units, but apparently similar in linkage and stability. It is quite unjustifiable to regard them as all of equal biological value. Their availability no doubt varies considerably, and there is the interesting possibility that certain groups might be preferentially removed, leaving new intermediate residues. Long-period fermentations do not seem to show the ultimate accumulation of any more resistant hemicellulose groupings, but it would be interesting in this connection to examine the individual fractions obtainable from straw which had undergone fermentation for a few days only, up to the end of the period of maximum initial loss of hemicelluloses.

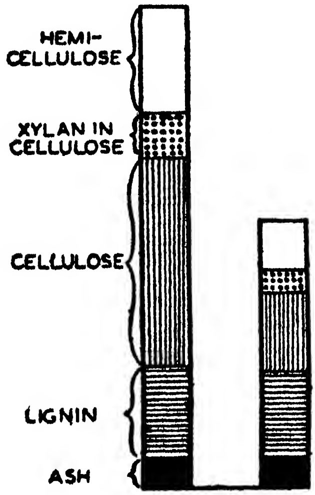

FIG. 2.—Approximate change in structural constituents of Oat straw during 2½ months decomposition.

There is some controversy as to the extent of the decomposition of lignin by general and soil micro-organisms. It is known

that certain special wood-destroying fungi (*e.g. Merulius, Polyporus, Trametes*) are capable of attacking and removing some lignin from wood, but in the case of general soil organisms the consensus of opinion is that lignin is decomposed only to a very limited extent. Two recent papers have, however, supported a rather different view. Waksman and Gerretsen (1931), contrary to earlier published work by the first-named, found that the lignin of straw is considerably attacked, and that its removal is especially influenced by temperature. At 37° C. over 30 per cent. of the lignin was removed in three and a half months and 50 to 60 per cent. in nine months, while at 7° C. the loss was slight. Phillips, Wiehe, and Smith (1930) similarly determined the lignin contents of a number of plant materials before and after decomposition and concluded that lignin was very readily decomposed. In several cases cited by them 40 to 50 per cent. of the lignin was removed in a relatively short period, a higher percentage loss than that sustained by the cellulose in the same time! However, the erratic nature of certain of the analyses given by these workers indicates that their results must be accepted with some reserve. Lignin estimations are deceptively difficult to carry out, and unsatisfactory at best. Being of such an inert character, direct estimation of lignin is impossible, and an " exclusive " method has to be adopted, based on its resistance to very strong acids. It is certain that the lignin is changed in some way by such a treatment, since the final product differs in methyl and acetyl content. The fineness of grinding of the plant tissue is of very considerable importance. To obtain consistent results the particle size should be uniform, both in the original samples and those taken after decomposition. A more direct method of estimation would be of great service in clearing up this disputed situation—perhaps some development of the new glycol method proposed by Hibbert and Rowley (1930) may prove serviceable. In general, the present evidence points to the relative unavailability of lignin during the active phases of the decomposition of a plant material, followed by an apparent slow degradation as the decomposition is prolonged.

IV. Synthesis—the Elaboration of Microbial Tissue

As emphasised previously, the decomposition of plant materials is essentially the assimilation by micro-organisms of certain of the constituents. The carbonaceous materials are employed chiefly as a source of energy, but to a small extent for structural purposes also. A rapid and extensive rot implies the development of an immense number of organisms for the growth of which an adequate supply of available nitrogen is essential

for conversion to microbial protein. If the nitrogen be supplied in an inorganic form, for example, as ammonium carbonate, the rate of its conversion or "immobilisation" is a measure of the rate of development of the organisms. Fungi may contain from 2 to 8 per cent. nitrogen, 4 to 6 per cent. being the amount generally found. The nitrogen contents of bacteria have been less widely determined, but the figures in general are higher than in the case of fungi and may even be as high as 10 per cent. If too little nitrogen is present, the active flora will be restricted in its development and the time taken for a given percentage decomposition will therefore be much increased. It is important to emphasise that a shortage of nitrogen has its effect on the rate of decomposition rather than the extent, and that ultimately the plant materials concerned will probably undergo similar losses. Under natural conditions the nitrogen supply is frequently a limiting factor. Any particular plant material decomposing in the presence of an excess of nitrogen is capable of causing the immobilisation of a certain and definite quantity as microbial protein. Hutchinson and Richards (1921) were the first to recognise the quantitative importance of nitrogen in decomposition. They determined the amount immobilised by a number of materials. For common straws, of low nitrogen content, they found an additional amount of 0·7–0·8 g. N. per 100 g. original material to be necessary. This quantity they termed the "nitrogen factor." It may be rigidly defined as that additional amount of inorganic nitrogen converted to the organic form by 100 g. of any material undergoing decomposition. The following diagram taken from Rege (1927) shows how the "nitrogen factor" changes as decomposition proceeds. It is seen that the most rapid period of conversion of inorganic nitrogen to organic, or in other words the period of most rapid development of microbial tissue, is in the first few days, just prior to the period when the rice straw in question suffered its heaviest loss.

In decomposition studies it is practically always found that the losses of the various constituents, cellulose, hemicelluloses, etc., together amount to more than the apparent total loss of organic matter. It will be readily seen that this apparent discrepancy is accounted for by the microbial tissue synthesised. It is possible to form some estimate of the amount elaborated from the "nitrogen factor" figures. In the example given above, 100 g. of rice straw is reduced to 55 g. at the end of forty days, and 0·9 g. of N. has been immobilised. In the completely rotted material therefore, ignoring the original plant protein, there would be 1·64 per cent. N. present as microbial protein. If it be assumed that mixed microbial tissue contains 5 per cent. N., this will indicate about 30 per cent. of the rotted

material as microbial tissue. In point of fact, it is not usually so high as this, and 20 per cent. is a more normal figure. It must not be supposed that inorganic nitrogen once converted to the organic form as microbial protein is stable as such. It is of necessity so only as long as the organisms are active. In normal decompositions there is undoubtedly a sequence of active forms, and there is little doubt but that nitrogen converted to microbial protein by one organism may subsequently be utilised by another. The " nitrogen factor " of a material in an incomplete stage of decomposition is frequently higher than

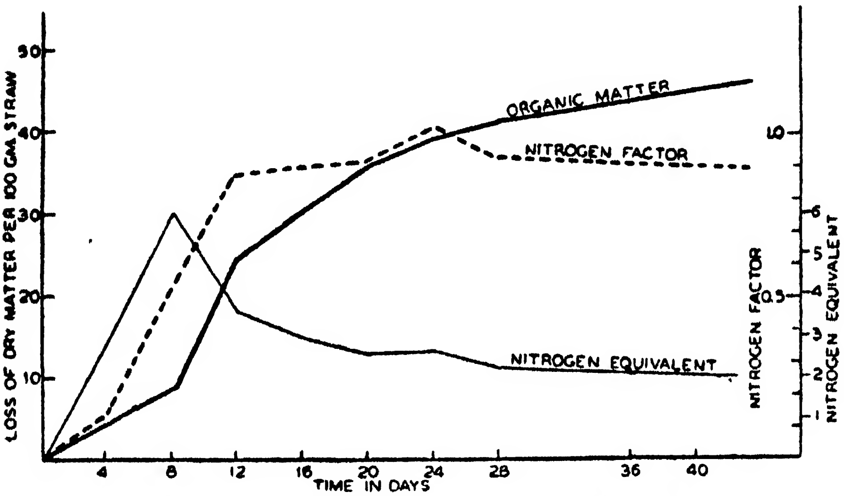

FIG. 3.—The immobilisation of nitrogen during the decomposition of rice straw (Rege).

later, when a condition of stability has been attained and all readily available constituents have been removed. The fall in " nitrogen factor " which occurs in such cases is due to the ammonification, or as it is termed by Jensen (1929) the " mineralisation," of a portion of the synthesised protein. In the example given above it will be seen that the " nitrogen factor " at the end of twenty-four days was 1·02 as opposed to 0·9 at the end of forty days, and that protein containing 0·12 g. N. on a basis of 100 g. of original straw has been decomposed and the nitrogen liberated. The " nitrogen factor " represents therefore only the equilibrium between immobilisation on the one hand and ammonification on the other, and does not necessarily represent the whole of the nitrogen actively involved in decomposition.

An investigation was recently made by Richards and Norman (1931) to determine the relationship, if any, between

the chemical composition of plant materials and the quantity of inorganic nitrogen immobilised during decomposition. Though they found it possible to indicate approximately what the " nitrogen factor " is likely to be, knowing the general composition of the material, they were unable to discover any absolute basis for prediction. Two variables exist which it is impossible to estimate. In the first place structural and physical differences between plant tissues must considerably influence biological availability, but cannot be assessed by chemical means. In the second place, it is not possible to follow entirely the changes of nitrogen in decomposition, but only those affecting the added inorganic nitrogen. This may or may not be the whole picture. It is impossible to learn whether the natural proteins of the plant tissue are also utilised. If they are, then the total nitrogen " active " as microbial tissue would be in excess of the " nitrogen factor," and the latter is merely the difference between the total nitrogen requirement of that plant tissue in decomposition and the amount liberated and utilised from the plant proteins. Plant materials already containing sufficient or more than sufficient nitrogen for decomposition may nevertheless temporarily immobilise an additional amount owing to preferential utilisation of the inorganic form.

By following the immobilisation of added available nitrogen it is possible, as has been shown, to obtain some information on the rate of development of microbial tissue. But the " nitrogen factor " is an expression which bears no reference to the efficiency of the flora present in decomposing the plant material. If, however, the nitrogen requirements are recalculated on the basis of the apparent organic matter removed, a new expression is obtained which is some measure of the activity or efficiency in decomposition of the organisms present. The term " structural nitrogen equivalent " or " nitrogen equivalent " has been suggested for this factor (Norman, 1931, i). It may be defined as the nitrogen immobilised in the removal of 100 g. of organic matter from any material. Like the " nitrogen factor," it is a summation of the microbial activities and is apparent rather than absolute. Its chief value lies in the comparison of the activities of pure cultures of organisms, or of a given mixed flora under different environmental conditions. As an example of its use in the case of a mixed flora, the figures have been calculated for Rege's data on the decomposition of rice straw, and are shown in Fig. 3. The final value for the nitrogen equivalent in this experiment is 1·9, a figure somewhat higher than that usually obtained. A plant material of low nitrogen content, suffering a 50 per cent. decomposition and giving a " nitrogen factor " of 0·75, would have a final " nitrogen equivalent " of 1·5.

V. Biological Factors

Since this review is primarily concerned with the chemical aspects of decomposition it is not proposed to treat at length the biological factors. The normal population of the soil is a heterogeneous community, the individuals of which are competing for available nutrients. In the presence of an ample supply of organic matter, multiplication is intense, and the resultant of the activities of the community is the decomposition of the material. Bacteria were originally held to be the organisms chiefly responsible for these changes, but more recently the importance of other heterotrophic groups has been recognised. Scales (1915) demonstrated the ability of many fungi to decompose cellulose, and some writers, such as Daszewska (1913) and especially Waksman (1924), have suggested that fungi are mainly responsible for the decomposition of plant materials in the soil. Many actinomycetes, too, have been demonstrated to be cellulose-decomposers, and, as they are common members of the soil microflora, an important place has been assigned to them by several workers (Waksman and Curtis, 1918). The addition of plant materials to the soil is accompanied under normal conditions by a tremendous development of both fungi and actinomycetes.

Pure cultural studies which have recently been made by Waksman (1931) and Norman (1931, i) on the decomposition of cellulosic materials by individual organisms have emphasised the omnivorous nature of the fungi and actinomycetes. The members of these groups which have been studied seem very similar in their activities and in their power of utilising the various straw constituents, varying only in the extent of decomposition effected. No organism has, however, been found which can bring about a decomposition as rapidly or as extensively as a mixed soil flora. It is much to be regretted that the many mesophilic cellulose-decomposing bacteria which have been isolated have not more frequently been tested for their ability to decompose natural cellulosic material, as opposed to pure cellulose. In the few cases in which this has been done the bacteria have been found to be relatively inactive. Bacteria in general seem to be more specialised in their nutritive requirements than are the fungi. In a normal mixed-flora-decomposition there is undoubtedly a sequence of active forms ; the fungi, because of the rapidity of their development in the presence of any easily available organic matter, are probably most important in the opening stages but seem to decrease in activity and importance as the fermentation proceeds, and bacteria and actinomycetes then become the predominant forms.

A discussion of the relative importance of these groups is not

merely of academic interest, but of practical significance, since a modification of environmental conditions may favour one type as against another and so alter the course of the decomposition. For example, under waterlogged and partially anaerobic conditions the activities of fungi and actinomycetes may be suppressed, and bacteria alone become mainly responsible for the changes which take place. This is well illustrated by the work of Waksman (1930) on the microbiological genesis of peats. Changes in moisture content may alter the balance, the actinomycetes being less affected than the bacteria by water shortage. The reaction of the medium too is of importance, acid conditions favouring fungal development and tending to suppress the activities of actinomycetes and bacteria. Small variations in reaction, however, have little effect on the ultimate result of the decomposition processes. The route and rate of the process may be altered a little but the residues appear to be practically identical (Norman, 1931, ii). The natural decomposition of plant tissues should probably be viewed as a co-operative decomposition of a high order of efficiency. Bacteria and fungi working together are in general peculiarly efficient. No fungi nor mixture of bacteria alone seem to be capable of effecting such an extensive decomposition as a mixed flora containing both, probably because the cycles of metabolism of these two groups, as indicated by their different efficiencies in the utilisation of energy materials, are of a different order. There is a need for further experimental work on the effects of the association of one type or organism with another in this type of fermentation.

VI. Summary

The natural decomposition of plant materials, whether in soil or alone, is a microbiological process in which the carbonaceous constituents of the tissue are utilised by organisms for their growth and development. The various constituents of plant material vary in availability, and accordingly the extent of decomposition depends on the composition of the material in question. The hemicelluloses and cellulose are readily available, the former being removed early in the decomposition process, while lignin is almost unavailable and appears proportionately to accumulate as rotting proceeds. The elaboration of microbial tissue calls for the presence of a considerable quantity of nitrogen in an available form. This nitrogen is transformed to microbial protein. Both phosphate and potash, and other inorganic ions, are similarly immobilised during this process, but the quantities necessary are small compared with the requirements of nitrogen. In the soil the nitrogen and inorganic ions thus withdrawn are temporarily unavailable to

higher plants, though they may subsequently be liberated when the supply of carbonaceous material is exhausted. The amount of organic matter present, and its availability, may therefore determine the nitrogenous balance of a soil, and its immediate fertility towards higher plants.

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GEORGE EDWARDS, F.R.S. (1694—1773)

AN EIGHTEENTH-CENTURY NATURALIST

By T. E. JAMES

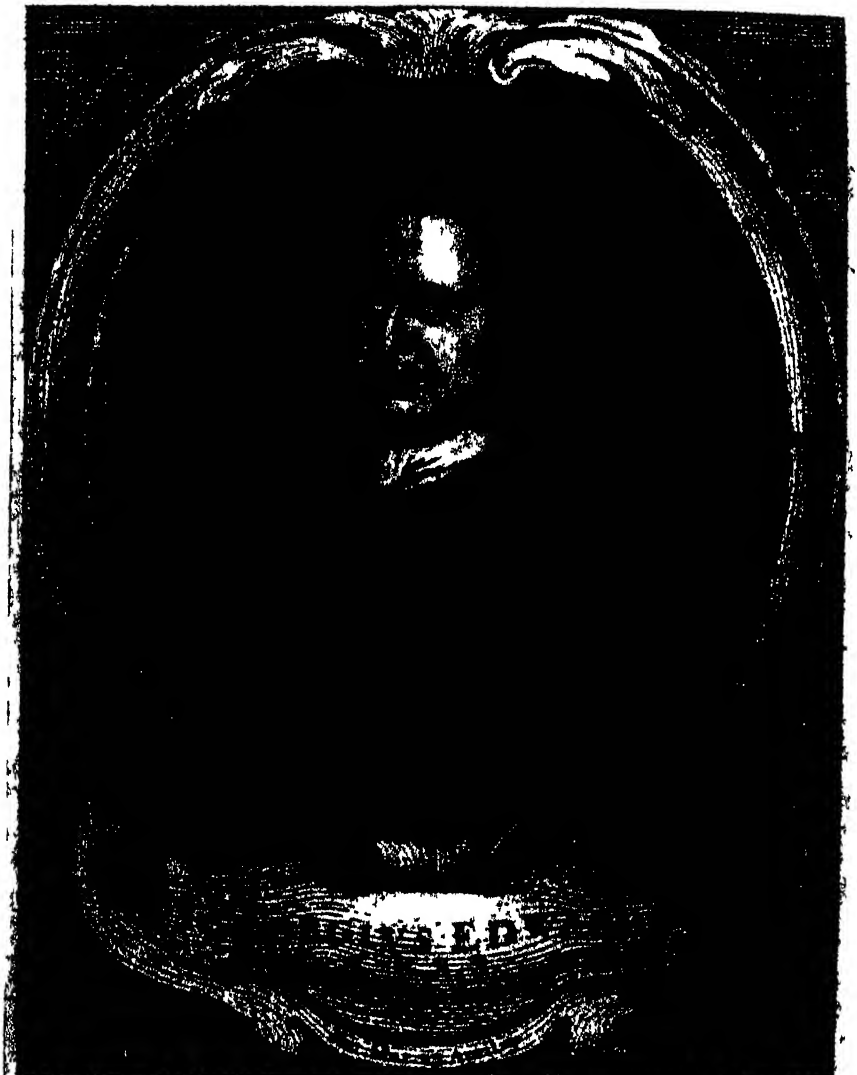
Sometime Clerk and Assistant Librarian to the Royal Society of London

On St. Andrew's Day in the year 1750 George Edwards, library-keeper of the Royal College of Physicians, attended the Royal Society's house in Crane Court, Fleet Street, to receive the Copley medal at the hands of Martin Folkes, president of the Society. The award was made in recognition of a published work in natural history; and was specified as follows: "On account of a very curious Book lately published, intitled *A Natural History of Birds*, containing the figures elegantly drawn and illuminated in their proper colours, of 209 different Birds, and about 20 very rare quadrupeds, serpents, fishes and animals."

In continuation parts that were issued, Edwards took the opportunity to express and emphasise his gratitude to the president and council for the distinguishing mark of favour they had been pleased to confer on St. Andrew's Day.[1] "It might" (he wrote) "be deemed an unpardonable omission and neglect to forbear to return my humble thanks to the president and council, as well as to the other members of that learned and useful body, many of whom have, I know, been instrumental in procuring me their favour." Further, he placed upon his title pages a finely engraved reproduction of the obverse and reverse of the medal, set in a framework of artistic embellishments. The honour itself was, at the time, unusual in character, inasmuch as it related to the issue of a book and not to defined philosophical research. As instances in connection, the recipients of the Copley gift, immediately before and after Edwards, were John Harrison and John Canton.

There is much in the life of this eighteenth-century naturalist to compel attention; and, as we shall see presently, something that is relative to present-day interests. He had a large circle of friends and acquaintances amongst the nobility and gentry of the kingdom, and he was well known to the men of science

[1] The hour of the Anniversary was then 10 a.m.



GEORGE EDWARDS, F.R.S., AGED 60.

("Your portrait in my study brings you every day before me, and reminds me of your indefatigable assiduity in collecting, delineating, and describing."—Linnæus to Edwards, March 20, 1758.)

By courtesy of the Royal College of Physicians.

of his period. He enjoyed the friendship of Linnæus (maybe they met), and correspondence between them can be seen in at least one of the learned societies of London. A fellow of the Royal Society, no fewer than six successive presidents occupied the chair whilst he lived. Critics may say that Edwards left the determination of genera and species to others. That is true. He was, in the main, a painter-copyist, but one of signal and outstanding merit. From contemporary records we know that to those persons who had a liking for studies akin to his own, he was an entertaining and communicative companion.

An Essex man, George Edwards was born at Stratford, on April 3, 1694. He never married. In boyhood he had the pupilage of a clergyman at a school at Leytonstone. Leaving there, he took lessons in accounts and general commerce, and following this was bound apprentice to a tradesman, remaining seven years. In after life, recalling school days, he remarks, " in trade there could not be found a Reverend Master, to place me with ; I was placed with the son of a Levite, Mr. John Dod, of Fenchurch Street, London, an exceeding strict Christian of our Established Church, nevertheless a finished scholar in the Greek and Latin languages, tho' a Man in Trade." Fortunate and unlooked-for circumstances at this stage gave Edwards access to a library embracing voyages, travels, astronomy, experimental philosophy, natural history, and painting. On his own word, confused in the head with such a mixture, and possessing a small patrimony, he put business aside and set out (1716) on a voyage to Holland. It was the beginning of considerable European travel. In a monograph (1747) he inserts a coloured map of Europe—" Itinera varia Auctoris," indicating on this by lines and dates his past voyages and his journeys on land. In rather caustic vein he tells readers : " I expect it will be asked what Business I had, or what I did in these Foreign Parts ? Therefore to satisfy the Curiosity of such as think it worth their while to read it ; and to save them the trouble of asking me any Questions, I shall inform everyone that it was meer Curiosity led me abroad, which is commonly termed no Business at all." In 1718 Edwards visited Norway. A quaint comment thereon : " I take this country to be one of the least polite, except Lapland," seems, from the context, to be impersonal, and to refer only to barriers of a physical nature.

Back in England (1721), Edwards resided for the next ten years in or near London, devoting himself, with ardour, to the portrayal in colour of selected zoological and botanical subjects, finding many highly placed patrons, not least amongst these Sir Hans Sloane. And Edwards calls to mind examples of his art that had been inspected either at public academies or at private houses, some setting apart particular days, weekly,

"for the assembling of knowing and inquisitive searchers after nature." In all this work we see a steadily growing reputation; moreover, the *Natural History of Uncommon Birds* in the making.

In 1733 fortune's wheel brought a new direction for effort. Edwards was appointed library-keeper to the Royal College of Physicians, and on the recommendation of Sir Hans Sloane. The latter was not only president of the College at the time, but also president of the Royal Society. Incidentally, it may be mentioned that the home of the Physicians was then situate in Warwick Lane in the City. A stately edifice had replaced the quarters destroyed in the Fire, and was opened in 1674. Though attributed to Wren, it is probable (as Dr. R. T. Gunther has shown) that Robert Hooke had the chief concern in its design and erection for the College. Edwards was granted apartments in the building, and we note that soon his books are described as "Printed for the author at the College of Physicians in Warwick Lane." It was a happy appointment, securing leisure and congenial opportunities not otherwise obtainable; doubtless the far-seeing Sloane had this in mind.

In 1757 Edwards was elected a fellow of the Royal Society[1]; thus seven years after he had been made a Copley medallist. Earlier (1752) the Society of Antiquaries elected him a fellow.

Foreshadowing now a scheme of publication, Edwards announces:

"I have been collecting for more than twenty years, and for a good part of the time employ'd by many curious gentlemen in London to draw rare foreign birds as they were possess'd of, and never neglected to take draughts of them with their permission for my own collection; and having stored up some hundreds, I showed them from time to time to curious gentlemen who favour'd me with their visits, and in looking them over several of them have told me that there were many amongst them that had not been figured or described by any Author, and that it would be worth my while to publish them, but I was backward in resolving to do it because I knew not so much of many of the Birds, as to know from what Country they came from, which is very material in Natural History. They answered that as I had taken the Draughts from Nature, and the like Birds might never be met with again it was better to preserve the Figures without knowing their countries, than not at all."

The materials for the *Natural History of Uncommon Birds* and *Gleanings of Natural History* covered, as we have already gathered, twenty years of original effort. Published in quarto

[1] The Earl of Macclesfield was then P.R.S.

form and issued in parts to subscribers, volume titles were afterwards given. In the *Gleanings*, descriptive letterpress occupied parallel columns in English and French. The first completed volume of the *Natural History* appeared in 1743, and the whole series came to a finish in 1764. Together, some hundreds of zoological subjects were delineated in colour; that is, in the hues of life. There were various dedications; first to the President and fellows of the Royal College of Physicians; a second to Sir Hans Sloane—" Suffer me " (Edwards writes) " to cast this weak Essay (towards Natural Knowledge) into your boundless Treasury of Nature, that it may be supported by your charitable protection, and skreen'd under your Illustrious Name from the Malice of Detractors."

In prefaces, forewords, and appendices lengthy space is given to personal, social, and general matters, of which a good deal is extraneous to the purposes of the series. But, however that may be, these departures reveal the man, and are acceptable reading in spite of vexing alternations of humility and the occasional assumption of a belated pomposity. We like him the better for the following: " As I never till very lately had any design to appear in Print, I have neglected to study the art of writing correctly, and am sensible of the many faults that may be found in this Book; but hope the candid Reader will overlook them, since my chief aim was rather to be understood than to write correctly."

The subjoined specimen of descriptive matter is from the *Gleanings*:

" LA POMPADOUR

" This is one of those Birds taken in a French prize by the now Earl Ferrers. They were said to be for Madam Pompadour. It being a Bird of excessive beauty, I hope that Lady will forgive me calling it by that name. It is a native of Cayana, in South America."

Sir Hans Sloane maintained until the end of his life (he died in 1753) an intimate, one might almost say affectionate, relationship with Edwards. The naturalist was a regular visitor to Chelsea in Sloane's closing years, carrying news of the scientific world, especially of what was happening weekly at the Royal Society's meetings. And Sloane was insistent upon bearing the expense of these journeys from London, whether coach-hire or waterage charges. Also, in affairs of charitable bounty to old associates in need, he relied on inquiries made by Edwards into the merits of such petitioners, and would entrust him with the means of assistance.

The Linnean Society of London has recently come into

possession (through donation [1]) of a set of Edwards's works which have annotations by a contemporary of Edwards, one Henry Seymer, of Hanford, Dorset. In these volumes the Linnean name of each subject depicted is hand written by Seymer on the plates and in accordance with the *Systema Naturæ* of Linnæus (12th ed.). Further, in Part II of the *Gleanings* (p. 267) an original colour drawing by Edwards is inserted, on which is written " Geo. Edwards, *sculpsit et pinxit*, May 1760." Added interest attaches to this desirable donation, for at the end of the same volume, an etched print of a finch is pasted in, on which is written, " Edwards's first tryal at Etching, A.D. 1739." We may perhaps assume that Edwards sent this print to Seymer in proof of his (lately acquired) ability in the art of etching on copper.

Justly annoyed at the piratical use of his figures, or portions of them, that was current practice, Edwards delivered an opinion thus : " I have observed that several of our manufacturers that imitate China Ware, several print sellers, and printers of linen and cotton cloths, have filled the shops in London with images, pictures, and prints, modelled, copied, or drawn, and coloured, after the figures in my *History of Birds*. . . . Most of wit, knowledge, and public occurrences, have also in their magazines, Mercuries, etc. made free with my figures and descriptions of animals to embellish their pamphlets, though the figures are generally so miserably lamed and distorted that the judicious part of the world can form but a mean opinion of the work from which they are plunder'd."

Recently it has come to light that among the plagiarists included in the indictment above were the craftsmen of the famous Chelsea Porcelain Factory. This interesting information is due to the researches of Dr. H. Bellamy Gardner, a London collector and student of the Chelsea productions. Looking for the source of the designs for a tureen and plates of Chelsea porcelain, " painted with Sir Hans Sloane's flowers," mentioned in a sale catalogue of 1758, he was led to Edwards's *Natural History of Uncommon Birds*, and he found that sixteen or more subjects therein formed the origins of certain birds in the Ware, reproduced in practically all their brilliancy of colouring. In the *Transactions* of the " English Porcelain Circle " (1931) a privately printed and ornately illustrated issue, Dr. Gardner has given the results of his investigation under the title, " The Chelsea Birds." However, time has mitigated these acts of appropriation, the while posterity regards such examples of the potter's art as choice and enviable possessions. I am indebted to Dr. Gardner for the accompanying reproduction of one of the Chelsea examples he traced (Fig. 2).

[1] By Major Vivian Seymer, D.S.O., M.C.

FIG. 2

Above: THE TOURACO FROM A COLOURED DRAWING BY GEORGE EDWARDS.

Below: A CHELSEA MODEL BASED ON EDWARDS'S DRAWING.

By permission from "The Transactions of the English Porcelain Circle."

Edwards's descriptive account is appended :

"THE TOURACO

" This bird is about the bigness of a Magpye or Jay. It is very active flurting up its tail, and raising its crest ; it swells its throat and utters a hoarse and disagreeable sound. This bird is now living at Colonel Lowther's house in St. James's Park, where I have been permitted to make drawings of it." [1]

Yet another runs thus :

"THE WHIP-POOR WILL, OR LESSER-GOAT-SUCKER

" In Virginia it is thus called from its cry. . . . They are seldom seen in the daytime. The Indians imagine these birds are the souls of their Ancestors slaughtered by the English, and say that they never appeared in their country before that slaughter."

The counsel and assistance of certain painters, " particular friends," had been solicited regarding accessory embellishments. In some of the plates where the birds were very small, butterflies, wasps and other insects, and flowers were added to fill up naked spaces.

Jealous of his reputation, Edwards resolved not to part with any of the prints, uncoloured, whilst he lived, lest they should be coloured by unskilful people, which might be a blemish to the work by being seen and taken for his colourings. Hence a copy carefully and exactly coloured from the original drawings was deposited in the library of the College of Physicians to serve as a standard of reference. Also, " I design to lodge this *History of Birds* compleat, and justly coloured, in the library of the Royal Society."

We may fittingly conclude this general biographical notice by reproducing two letters from Edwards to Linnæus, preserved in the Archives of the Linnean Society of London.

Date, about 1758-9.

To C. Linnæus.

" SR.

" I received your Complyments by Our Good friend Mr. Ellis and am very Glad to hear you Still persue the Studies of Nature in which you are already so far advanced as to Draw on you the Eyes of all the Naturalists in Europe, I wish you hartely to goe on and prosper. As it will be some Months before I can publish a work I have now in hand and knowig your thirst for the earlyes in sight of what is going forward

[1] Edwards's charming colour drawing of this bird is the origin of the Chelsea Model No. 139, in the Schreiber Collection.

in natural history, I have herewith sent you 75 prints[1] with a ful Confidence that you will make no use of them to My disadvantage. I believe before the next winter is Over the letter press part will be ready to be delivered with the Setts of Prints I am now colouring, yet I thought this Smal present of black prints might be acseptable to you in the mean time.

" I am Sr. with the Greatest respect Your

" Most Humbl and Most Obedient Servant,

" George Edwards."

To Sr. Charles Linnæus, Baronet,
from his Obliged Humble Servant,
Geo. Edwards.

" Sr.

" I herewith Deliver to the Obligin Mr. Solander to be Conveyed to you a Compleet coppy of the letter Press of My Gleanings of Natural History, together with 25 black Prints, which added unto 75 prints formerly sent to you Makes 100 Prints which Answer to the hundred Chapters contained in the Gleanings of Natural History. I have also sent such part of the Letter impression of the Second part of the Gleanins to Compleat which was formerly Deliver'd and payd for by Mr. Beirkin. I have received the very great favour of your most kind and Obliging Epistle by the hands of the highly accomplished Mr. Solander, who I shal do all in my Power to Oblige. I wish I were a little younger that I might be the more able to answer and return the Obligations of my Friends in many parts, but they must excuse the Slowness of old age, becaus it is an infirmety of nature. I return you my thanks for all former favours and hope for a continuation of your agreeable correspondance."

London,
August 1760.

Writing from the College library on May 1, 1769, Edwards informed his friends that he had sold and delivered to James Robson, bookseller, The Feathers, New Bond Street, all remaining copies of his natural history works, and everything appertaining thereto. In a humble spirit he offers thanks to the nobility, gentry, and others for long-continued favours and support. " Sight and steadiness of hand begin to fail me," he

[1] On most of these Linnæus has himself affixed the Latin names of the species.

tells us. So the old naturalist-librarian, well content, if we judge aright, resigned service with the College of Physicians, and Warwick Lane knew him no more. His life had been peaceful, unhurried, without hindrance, one thought uppermost, how best to serve natural knowledge from his chosen standpoint.

Edwards died July 23, 1773, in the eightieth year of his age, and was buried in the churchyard of West Ham. A memorial stone chronicled his association with the Royal College of Physicians, recording further, that "His Natural History of Birds will remain a lasting Monument of his Knowledge and Ingenuity."

POPULAR SCIENCE

REARING MARINE ANIMALS IN A PLUNGER JAR

By MARIE V. LEBOUR, D.Sc., F.Z.S.

Naturalist at the Plymouth Marine Laboratory

The method of keeping small animals alive in an aquarium known as a plunger jar was first introduced by Mr. E. T. Browne, the well-known authority on cœlenterates, who in 1897[1] described the apparatus which was originally devised as a means of keeping small jelly-fishes alive in the laboratory. Since then it has proved invaluable both for keeping the sea animals alive and for rearing the larvæ.

The principle of the plunger jar is to create a movement in the water of a small aquarium in order that the live animals in it should not remain still, but be stirred up by the currents created and kept continually on the move. The aquarium is an inverted glass bell jar with its knob placed in a wooden stand and filled with sea water taken from some place as far away from land as possible to be free from contamination. In this jar there moves up and down rhythmically a glass plate, called the plunger, fixed to a glass rod (Fig. 1). The rod is tied loosely to a wooden beam resting on a pivot like the beam of a balance. At the other end of the beam is attached a tin can pierced below for a thick cork, the cork itself being perforated to allow the long end of a glass siphon with a thick bore to be introduced. Into this tin can dribbles water from a fresh-water tap through a piece of rubber tubing. The siphon is so arranged that the top reaches to about the middle of the can, the aperture of its short end near the bottom. The glass plate and tin can balance one another at either end of the beam. When the water dribbling into the can reaches the top of the siphon the latter empties the can, which rises, and at the same time the plunger falls. The plunger plate is so arranged, by the glass rod being slightly bent, that it is a little oblique, and pierces the surface film on the upward stroke, thus preventing organisms from being

[1] Browne, E. T.: 1897, "On keeping Medusæ alive in an Aquarium," *Journal of the Marine Biological Association*, (N.S.) vol. V, p. 176.

caught between the plunger and the film and also aerating the water to a certain extent. A wooden stop arrests the descent of the can when the plunger has reached the desired height. This is the original design for the plunger jar which is still in use in the Plymouth Laboratory, but the principle has been further extended, and many plungers in separate jars of various sizes are worked by an automatic bucket. Thus a large number of these plunger jars are available for experiments.

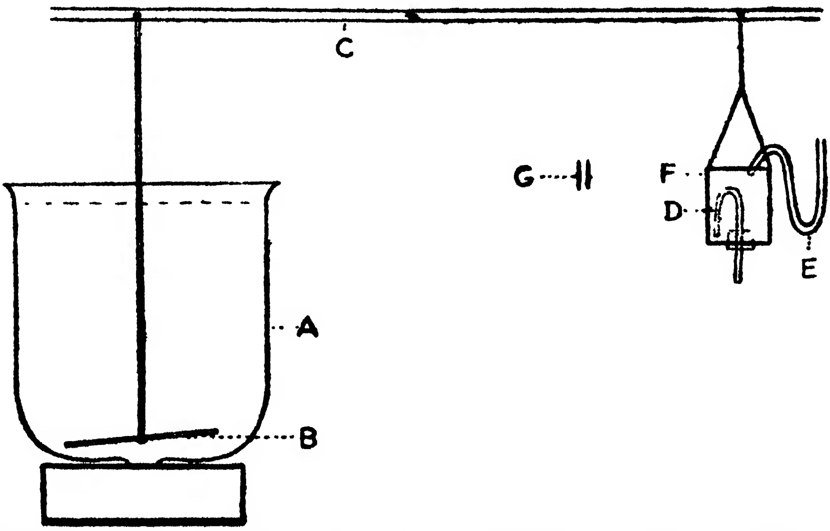


FIG. 1.—Diagram of plunger jar. A. Bell jar. B. Plunger. C. Beam. D. Siphon. E. Rubber tubing from fresh-water tap. F. Tin can. G. Rest.

At first the animals were fed on fresh plankton, and this is still used for keeping special species alive, but for rearing larvæ other methods have been devised. In 1900 Prof. E. W. MacBride [1] published a work on the rearing of echinoid larvæ. These he successfully reared in plunger jars by changing a large portion of the water frequently, thus giving the larvæ their natural food in the sea water itself without specially picking it out. The same year Prof. W. Garstang [2] described the successful rearing of the " Butterfly Blenny," *Blennius ocellaris*, in plunger jars, from the egg through the larval stages. These were fed on specially selected plankton which was removed frequently and a fresh supply given. The method has proved to be on the whole unsuitable to the rearing of fishes, only those

[1] MacBride, E. W.: 1900, " Notes on the Rearing of Echinoid Larvæ," *Journal of the Marine Biological Association*, (N.S.) vol. VI, p. 95.

[2] Garstang, W.: 1900, " Preliminary Experiments on the Rearing of Sea-Fish Larvæ," *Journal of the Marine Biological Association*, (N.S.) vol. VI, p. 70.

species which emerge from the egg in a late stage of development having any chance of coming through. The present writer has reared the marine stickleback *Spinachia vulgaris* from the egg to a length of about 3 in. in a plunger jar.

The researches of Dr. E. J. Allen and Dr. Allen with Mr. E. W. Nelson [1] in diatom cultures revolutionised the methods of rearing larvæ in plunger jars, and resulted in pure cultures of diatoms being obtained which were ideal for rearing small larvæ. The chief diatoms cultured were *Nitzschia closterium* and *Thalassiosira gravida* (Fig. 2), *Nitzschia* being almost exclusively

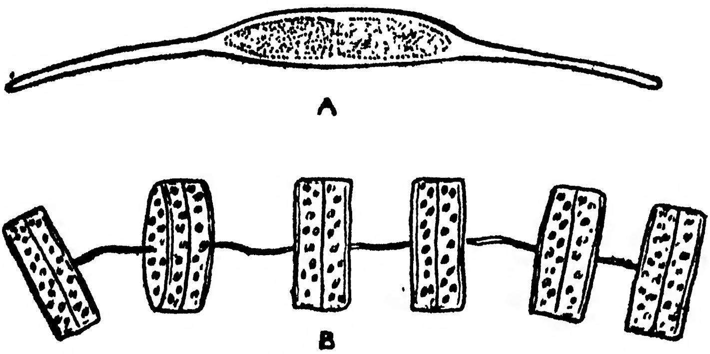


Fig. 2.—A. The Diatom *Nitzschia closterium*, 30μ long. B. *Thalassiosira gravida*, 20μ across.

used at the present time. An absolutely pure culture of *Nitzschia* is always kept going and subcultures are obtained from this. A few drops of the *Nitzschia* culture are added to the water (filtered or not) in the plunger jar, and the diatoms increase enormously, usually serving as adequate food during the whole larval life where a diatom diet is necessary. The water can be left unchanged for months. In this way many animals have been reared from the egg through their larval life, including echinoderms, annelids, and molluscs. It is even possible to rear them in London, Prof. MacBride and his pupils having been very successful in rearing echinoderms at the Imperial College of Science. Besides the many workers on echinoderms at the Plymouth Laboratory, including Dr. Mortensen and Prof. MacBride, Mr. D. P. Wilson, Assistant Naturalist at the Laboratory, has reared successfully several annelids, and the present writer has reared the gastropod *Nassarius reticulatus* from the egg to the crawling stage.

[1] Allen, E. J., and Nelson, E. W.: 1910, "On the Artificial Culture of Marine Planktonic Organisms," *Journal of the Marine Biological Association*, (N.S.) vol. VIII, No. 5.

Allen, E. J.: 1914, "On the Culture of the Plankton Diatom *Thalassiosira gravida* in Artificial Sea Water," *ibid.*, (N.S.) vol. X, No. 3.

For rearing the higher Crustacea animal food is necessary, and for the crabs it was found that very young molluscs, newly hatched, or developing echinoderms and annelids a day or two old answered the purpose. Larval oysters were employed in many cases. The English oyster keeps its newly hatched young in its gills, where they remain until they have shells and a swimming organ, the velum. If those oysters are taken which have very dark grey gills from being laden with these larvæ it is easy to pipette the larvæ out, and when placed in an aquarium they will immediately swim about. Such free-swimming larvæ are splendid food for the baby crabs. By making fertilisations of *Echinus* and of the annelid *Pomatoceros*, and using the resulting larvæ a day or two old, other good foods can be obtained, but the crabs do not feed on these so readily as they do on oyster larvæ. By thus feeding them with oyster larvæ several crabs were reared from the egg to the last larval stage or to the crab stage.

Three rearing experiments are described below from the present writer's own work. The first is the gastropod *Nassarius reticulatus* (*Nassa*), which was reared on diatoms; the other two, *Portunus puber* and *Inachus dorsettensis*, are crabs reared on oyster larvæ.

THE REARING OF *NASSARIUS RETICULATUS*[1] (L.)

Nassarius reticulatus, or *Nassa* as it is usually called, is a common British gastropod, very destructive to other molluscs, and often to be found in crab and lobster pots, its natural habitat being among stones and on mud flats at extreme low tide and beyond. Its eggs are laid in purse-like capsules in rows, usually on the sea-grass *Zostera* which is common along the coasts. Many eggs are contained in each capsule, all of which develop into young shells. Some of these capsules were obtained, removed from the *Zostera*, and placed in a plunger jar in which *Nitzschia* had been introduced. In the water were other diatoms, and these and the *Nitzschia* together were growing thickly when the larvæ were hatched. The larval *Nassarius reticulatus* hatches with a well-developed shell and bilobed velum, by means of which it swims about vigorously. As it grows the shell becomes spiral, the velum slightly four-lobed, and much larger with a brown border. When swimming the larva looks like a beautiful little butterfly. The velum is ciliated all along the edge and underneath, the two rows of cilia bordering a groove to the mouth. By means of these cilia the food is

[1] Lebour, M. V.: 1931, "The Larval Stages of *Nassarius reticulatus* and *Nassarius incrassatus*," *Journal of the Marine Biological Association*, (N.S.) vol. XVII, October 3.

wafted to the mouth, and for the whole of the larval life the food consists of diatoms. When about two months old the *Nassarius* has the velum at its largest, and the foot is well developed so that it can either crawl or swim. Soon after this the velum dwindles and the animal can no longer swim. It now crawls about like the adult, and its method of feeding is changed, for it is no

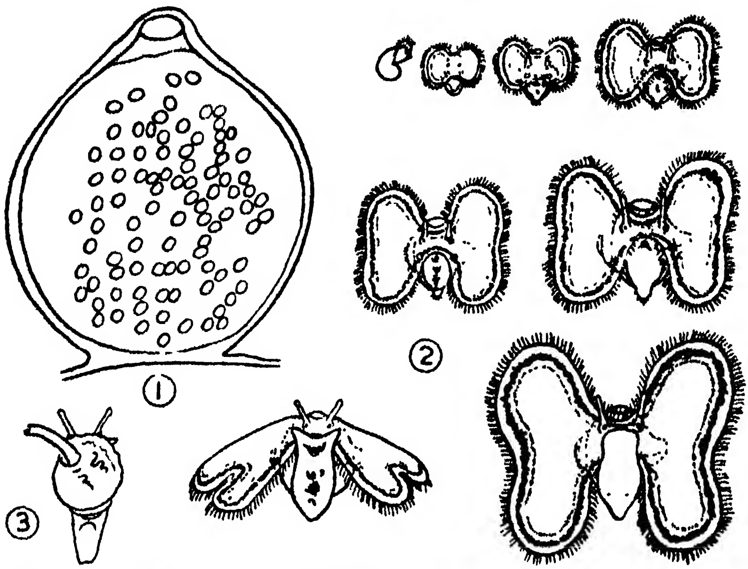


FIG. 3.—Larvæ and young of *Nassarius reticulatus* reared in plunger jar. 1. Egg capsule, 0·48 cm. high. 2. Larvæ, 0·25 mm. to 0·75 mm. across shell. 3. Young crawling stage, 0·75 mm.

longer a plankton feeder, but is carnivorous and eats small animals. Tiny bivalves introduced into the aquarium make good food. A closely related species *Nassarius incrassatus* was collected as a swimming larva and reared in a plunger jar on such small molluscs after the velum had disappeared. These reached to adult size within a year.

THE REARING OF *PORTUNUS PUBER*[1] (L.)

Portunus puber, the Velvet Swimming Crab, is the largest and one of the commonest of the British swimming crabs, occurring between and under stones at low water and beyond. Female crabs keep their eggs under the abdomen attached to the short abdominal legs. A "berried" female was obtained whose eggs were nearly ready to hatch. This was apparent by the eyes of the larval crabs being visible and giving the whole egg mass a dark appearance. The crab was placed in a large

[1] Lebour, M. V.: 1928, "The Larval Stages of the Plymouth Brachyura," *Proc. Zool. Soc. London*, July.

aquarium tank with running water. In a few days the eggs hatched out and rose to the surface of the water, where they were pipetted out into a plunger jar. At first the larvæ are covered by an embryonic cuticle with very large transparent spines on

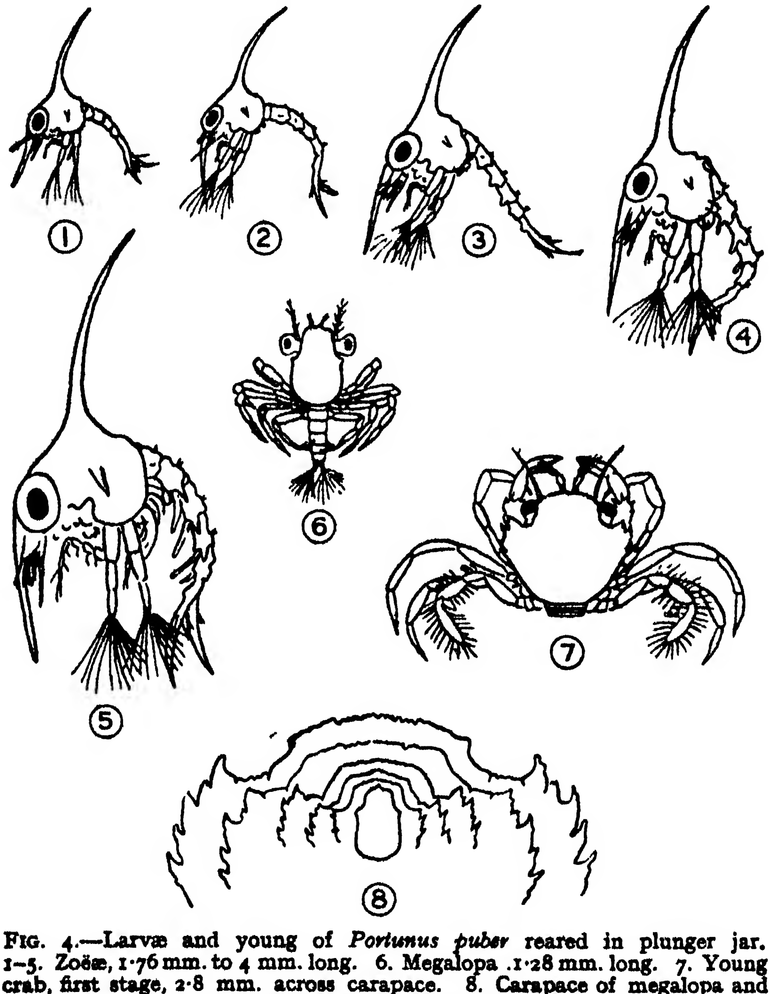


FIG. 4.—Larvæ and young of *Portunus puber* reared in plunger jar. 1–5. Zoëæ, 1·76 mm. to 4 mm. long. 6. Megalopa .1·28 mm. long. 7. Young crab, first stage, 2·8 mm. across carapace. 8. Carapace of megalopa and five successive crab stages (6–8 are half the scale of 1–5).

the feelers and tail, the true larval spines being hidden underneath this skin. This stage is known as the *pre-zoëa*. By means of much wriggling for some hours the larva casts this skin and emerges as a *zoëa*, having long spines on the body, well-developed jaws for eating, and two pairs of foot jaws with long setæ by means of which it swims. The little larvæ placed safely in a plunger jar, oyster larvæ taken from the gills of an oyster

were introduced and the zoëæ instantly began to feed. The food was frequently renewed, any remains falling to the bottom of the jar being removed at intervals. *Portunus puber*, after emerging from the embryonic cuticle, passes through five zoëal stages, *Inachus dorsettensis* through two only. During this time a change is gradually taking place in the larvæ. In all the zoëal stages there are two pairs of foot jaws used for swimming, the other appendages gradually appearing behind these. In the last zoëa the abdominal legs (pleopods) are well developed although not functional. From the last zoëa comes the megalopa (so called from its large eyes), which has all the appendages functional, the foot jaws now being proper feeding organs, the swimming being done by the pleopods. The megalopa can both swim and crawl, and eats planktonic animals usually larger than oyster larvæ. Both the later zoëæ and the megalopa can eat comparatively large Crustacea, frequently devouring their own species, especially if feeble or dying. It is, however, quite easy to keep the megalopæ alive and thriving on pieces of mussel. The common mussel, *Mytilus edulis*, was used for these experiments. The megalopæ were removed to another plunger jar or bowl and fed on pieces of mussel. From the megalopa comes the true crab, and from now onwards it gradually becomes like the adult.

The following dates show the rearing of one *Portunus puber* from the egg to the ninth young crab stage, sixteen stages in all. In this case the mother crab was in a large tank until the eggs were hatched; the larvæ were then removed with a pipette to a plunger jar, and reared until the megalopa stage on oyster larvæ. One megalopa was isolated in a glass bowl and fed on pieces of mussel, the water being changed every day, the resulting small crab placed in a plunger jar and fed on mussel until it died after the ninth moult :

Pre-zoëa from egg	June 23, 1927.
First zoëa from pre-zoëa	June 23, 1927.
Second zoëa from first	June 28, 1927.
Third zoëa from second	July 1, 1927.
Fourth zoëa from third	July 4, 1927.
Fifth zoëa from fourth	July 8, 1927.
Megalopa from fifth	July 12, 1927.
First young crab from megalopa	July 25, 1927.
Second young crab from first	August 1, 1927.
Third young crab from second	August 8, 1927.
Fourth young crab from third	August 17, 1927.
Fifth young crab from fourth	August 29, 1927.
Sixth young crab from fifth	September 7, 1927.
Seventh young crab from sixth	September 26, 1927.
Eighth young crab from seventh	November 21, 1927.
Ninth young crab from eighth	December 29, 1927.

(This last died in casting its skin.)

It is seen that whereas a few days may elapse between the changes of the zoëal stages, the intervals gradually enlarge until more than a month intervenes between the change from the eighth to the ninth young crab, under laboratory conditions. The temperature was in all cases the usual laboratory temperature.

The Rearing of *Inachus dorsettensis* [1]

Inachus dorsettensis (Pennant), the "Scorpion Spider Crab," the commonest spider crab at Plymouth, was reared from the egg to the seventh young crab stage. In this case the "berried" female, carrying her eggs which were nearly ready to hatch, was placed in a plunger jar and the newly hatched young removed to a fresh jar with oyster larvæ. The first zoëa from the pre-

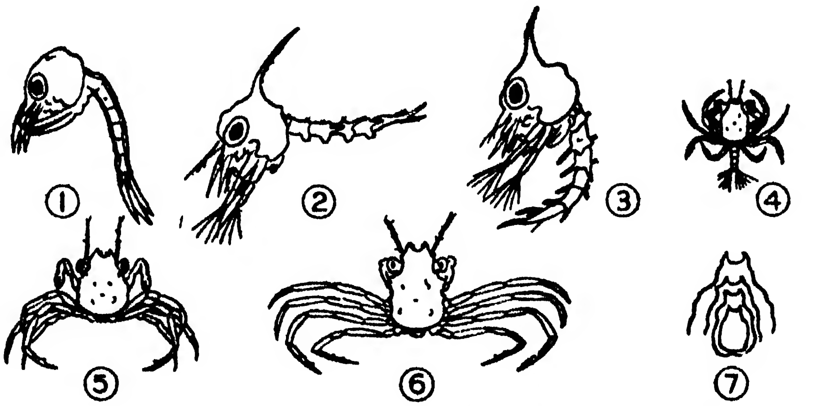


Fig. 5.—Larvæ and young of *Inachus dorsettensis* reared in plunger jar. 1. Prezoëa, 1·9 mm. long. 2–3. Zoëæ, 2·4 mm. to 2·9 mm. 4. Megalopa, 1·6 mm. 5. First young crab stage, 0·96 mm. across carapace. 6. Second young crab stage, 1·28 mm. across carapace. 7. Carapace of megalopa and three successive young crab stages. (4–7 are half the scale of 1–5.)

zoëa gives rise to the second zoëa, which is far advanced and changes into the megalopa. Again, one megalopa was isolated in a glass bowl, fed on mussel, and the resulting young crab transferred to a plunger jar, where it was fed on bits of mussel until it died in the seventh stage. The young crab from the megalopa directly it emerged covered itself with small bits of debris, and was successfully disguised in about an hour.

[1] Lebour, M. V.: 1927, "Studies of the Plymouth Brachyura. I. The Rearing of Crabs in Captivity with a Description of the Larval Stages in *Inachus dorsettensis*, *Macropodia longirostris*, and *Maia squinado*," *Journal of the Marine Biological Association*, (N.S.) vol. XV, 1, and Lebour, *op. cit.*, 1928.

The following dates show the changes of one crab :

Pre-zoëa from egg . .	June 12, 1927.
First zoëa from pre-zoëa .	June 12, 1927.
Second zoëa from first .	June 16, 1927.
Megalopa from second .	June 23, 1927.
First young crab from megalopa	July 4, 1927.
Second young crab from first	July 15, 1927.
Third young crab from second	July 26, 1927.
Fourth young crab from third	August 8, 1927.
Fifth young crab from fourth	August 17, 1927.
Sixth young crab from fifth	September 1, 1927.
Seventh young crab from sixth	October 1, 1927.

Again the intervals are longer between the changes as the crab grows.

The above notes show the possibilities of the plunger jar, which is certainly a most useful invention, and one which has stood the tests of time. It is hoped that many more interesting experiments will be made on the same lines in future years.

NOTES

Colour Films (G. B. B.)

On November 9, before a large audience at the rooms of the Royal Society of Arts, with Lord Rutherford in the chair, Dr. Thorne Baker gave a description of recent advances in colour cinematography accompanied by demonstrations. The first film shown was one which had been produced by Kodak Ltd. for ordinary amateur use in their well-known baby ciné camera. This is made on the lenticular film principle, that is to say, the film is covered by collodion, the surface of which is shaped by ruling in such a way as to make it act like a large number of elementary lenses. When, therefore, a tricolour filter is placed in front of the taking-lens, hundreds of small images of it are formed on the film, and the whole effect is similar to having a large number of coloured starch grains as in the Lumière process. For reproduction it is, of course, necessary to have a similar filter on the projector and the film must be similarly situated with respect to it. The film shown on the usual small aluminium-painted screen suffered from lack of sufficient illumination, but allowing for this, it certainly appeared that very pleasing results can be obtained by this method.

Dr. Baker next showed what he considers to be the highest level attainable by the two-colour method, a Technicolour film. The definition was excellent, but as regards colour it could not compare with the three-colour film shown afterwards, which was produced by the Spicer-Dufay process on which Dr. Baker has been working at Sawston. In this process the film is ruled alternately in stripes of green and orange dye and crossed with stripes of blue violet. Stripes similarly situated must, of course, occur on the film positive. The film shown with the full-size cinematograph projector was much better illuminated than the Kodak film, although even in this case it seemed that more light was required to make the colours really bright. The results, however, were excellent, and although it cannot yet be said that colour reproduction is perfect, nevertheless, the effects produced were very realistic and extremely pleasing to the eye. One defect was that, at a distance of thirty feet at least, the grain of crossed rulings (350 to the inch) was visible, and when once seen became annoying. This, doubtless, will be overcome.

Great care has to be taken with studio lighting, and at present a mixture of half-watt and carbon arc light is used. Dr. Baker made only a few modest references to some of the troubles encountered, but it was quite clear that almost insuperable difficulties have been overcome, and an enthusiastic audience agreed at the end with Sir William Bragg that the lecture and demonstration would be looked back to in the future as the occasion when colour films first proved themselves worthy to enhance the great art of the cinema.

A New Photometer for Ultra-Violet Spectrophotometry (A. H.)

The increasingly great use which is being made of absorption spectrophotometry is understandable when once the data that this technique will yield is realised. Thus, the relationship between absorption and chemical constitution, and the effect of solvents, may be studied ; organic substances can be identified and estimated whilst a great variety of biological substances (such as blood serum, cerebro-spinal fluid, vitamins A and D, etc.) come within the scope of the method.

With this extending use of absorption spectrophotometry has come the need for new apparatus which will increase the rapidity of the method and improve its accuracy, and the latest development here is the " Spekker " Ultra-Violet Photometer. This instrument is manufactured by Adam Hilger Ltd., whose sector photometer has been in wide use for this kind of measurement for many years now. The sector of this latter type of instrument, however, is responsible for the available intensity of illumination being cut to one-half, and it is mainly to overcome this that the " Spekker " photometer has been introduced. In both instruments the original beam is split into two, one of these passing through the substance under examination, the other passing through the comparison liquid. The absorption due to the substance in the first beam is then compensated for by cutting down the radiation in the second beam. In the sector instrument this reduction is achieved by the interposition of a revolving sector with a variable aperture ; in the new instrument a rectangular aperture is employed, and the size of this is controlled by means of a micrometer screw. The net result of the change is to give an instrument whose speed is about double that of the older instrument. Such an increase of speed is of great value in biochemistry and related subjects, where speed of working is essential because of the changes which may be taking place (due to irradiation, etc.) in the substance under examination.

Great care has been devoted to the optical system of this new instrument. A single light source is employed to give

both beams, and the fact that this source will undoubtedly fluctuate in intensity in use renders it essential that the same part, or very closely adjacent parts, of the source should be used for both beams, and that the aspect should be as nearly the same as possible. These conditions are observed in the " Spekker " photometer. The alignment of instruments of this type is also frequently a difficulty, but in this case special attention has been devoted to this, and two points are worthy of notice. Firstly, the light source is made an integral part of the instrument, and secondly, one end of the photometer is fastened to the spectrograph by means of an adapter attached to the spectrograph slit. It is claimed that by these means the major portion of the alignment is automatically obtained. A full description of this instrument will be found in " The Spekker Photometer for Ultra-Violet Spectrophotometry," F. Twyman, *Trans. Opt. Soc.*, vol. XXXIII, p. 9 (1931–2).

Improved Thermionic Valves (S. K. L.)

A series of wireless receiving valves having extraordinarily good characteristics has recently been introduced by Standard Telephones and Cables Ltd. An account of them is given in the issue of *The Wireless World* for August 5, 1932. These new " Micromesh " valves, as they are called, possess superior characteristics on account of the diminished spacing of the electrodes. The principle of operation is precisely the same as in the more usual types, but the construction is unique.

The valves are designed for operation from alternating-current mains, and the cathodes are therefore indirectly heated. The long cylindrical cathode is heated internally by crimped heater wires threaded in a twin-bore magnesia tube. Allowance is made for longitudinal thermal expansion, yet the mounting is perfectly rigid. The grid and anode are both very small, compared with the electrodes in ordinary valves, and they are both very close to the cathode. Such small clearances have been made possible only by extremely rigid mounting and rapid dissipation of heat. These most important requirements have been met by fitting both the grid and anode with large rectangular vanes. The cooling of the grid is so effective that there is no trace of grid emission even with the anode and cathode at dull red heat.

The complete range of " Micromesh " valves is not yet obtainable, but the few types at present on the market have characteristics greatly superior to those of the corresponding valves of orthodox design. For instance, the " goodness," or mutual conductance, of the output valve is 12·6 milliamps per volt, which is about twice that of the ordinary output valve.

Two or three years ago, such a figure would have been considered phenomenal. The special construction has proved entirely satisfactory in quantity production, and there now remains the development of the complete series of valves with the improved characteristics.

Electric Shock (S. K. L.)

A considerable amount of research work has been done recently at the Johns Hopkins University on the injuries to persons caused by electric shock. A paper by W. B. Kouwenhoven and O. R. Langworthy of that University published in the October 1932 number of *Electrical Engineering* discusses the effects and injuries arising from surge discharges and summarises the more important conclusions of earlier work. In the United States there are over one thousand fatalities from electric shocks annually, and the problem is regarded as one of increasing importance.

As supplementary to the case histories of several hundred human beings, investigations were made with rats and dogs. It has been found that animals differ widely in their ability to withstand shocks, and, on account of their particular reactions, rats were chosen for studies of the nervous system and dogs for studies of the heart. A small electrical impulse generator was used capable of passing 100 amps through the animal's body at a maximum of 200,000 volts. The maximum current was reached in $\frac{1}{2}$ microsecond, and the entire discharge was completed in about $4\frac{1}{2}$ microseconds. The results of the experiments with rats clearly emphasise the importance of the current path through the animal. It was observed that as the current path became more remote from the brain and nerve centres, the chances of recovery became greater. Further, it has been concluded that, in the case of rats, low-voltage A.C. shocks are more deadly than D.C. shocks of corresponding voltage, and that D.C. shocks of 1,000 volts are more deadly than A.C. shocks of the corresponding voltage, and that in either case the injury increases with the voltage.

Most accidents to human beings occur in circumstances where moisture reduces the contact resistance of the body to a negligible value. At high voltages, the contraction of the muscles is so violent that often the victim is thrown clear. At low voltages it is often difficult or impossible for the victim to release his hold because the contraction is steady rather than violent. In human beings, currents of 8 to 10 milliamps are quite painful; at 20 milliamps, the contraction of the muscles is so great that the victim cannot release his hold. Currents of 90 to 100 milliamps are considered dangerous. The sensitivity

of human beings and animals to electric current varies a great deal: the threshold is generally between 0·5 and 2 milliamps. The current density is also important: a small animal does not recover as readily as a large animal. The duration of contact is of extreme importance, and the hope of successful resuscitation is diminished as the time of contact and the voltage are increased. The paper emphasises once again the importance of immediate and sustained artificial respiration. It is gratifying to note that permanent injury is shown by only a very small percentage of the individuals who have recovered from an electric injury.

Thermionic Emission (S. K. L.)

Radio Research Special Report, No. 11 (London, H.M. Stationery Office. Price 2*s*. 6*d*. net) is a survey of the literature on thermionic emission recently compiled by W. S. Stiles, of the National Physical Laboratory, on behalf of the Radio Research Board. An endeavour has been made to include in it the most important papers up to the end of 1930. The survey is divided into nine sections and includes a bibliography and an author index.

The first section is a General Outline, which is an historical account of the outstanding developments beginning with the original work of Richardson and Wehnelt. The next two sections deal with the Theory of Temperature Emission of Electrons, and the Variation of Emission with Temperature, respectively, at considerable length. Details of the more important points in various theories are given, and several tables of various experimental results are included. The next four sections are short reviews of the Heat Effects in Thermionic Emission (the heats of evaporation and condensation of electrons), the Distribution of Velocity of Thermionic Electrons, the Schottky Effect (the effect of applied electric field at the surface of the emitter), and the Photo-thermionic Effect (the effect of light on thermionic emission), respectively. Thoriated Filaments and Oxide-coated Filaments form the subjects of the last two sections. These two types of filaments are of great commercial importance, and consequently have been studied in considerable detail. The survey of literature on thoriated filaments, with which are included other thin film emitters, is fairly comprehensive, but the section dealing with oxide-coated filaments is rather brief in view of the importance of this particular type.

The bibliography contains, in all, over 300 references, and there are blank pages to enable the reader to insert later references in the proper position. Also for this purpose, gaps have

been left in the numbering of the references, which are arranged in a decimal system of notation. Unfortunately, there are references in the text which cannot be found in the bibliography nor in the author index. There are also a few errors in the spelling of authors' names. If these faults can be overlooked, the book is worthy of high praise, for it brings together into the most orderly collection everything that has borne fruit in the very fertile field of thermionics.

Trichlorethylene (G. D.)

Trichlorethylene is probably the most important of the recently introduced non-inflammable, aliphatic halogen compounds. It is prepared by the action of " milk of lime " upon tetrachlorethane,

$$2CHCl_2 \cdot CHCl_2 + Ca(OH)_2 = CaCl_2 + 2H_2O + 2CHCl : CCl_2.$$

The commercial product is a pure, colourless liquid; its boiling-point (87° C.) is constant within a range of 1° C. The specific gravity is 1·475 at ordinary temperature, and the substance remains liquid until a temperature of − 73° C. is attained. Trichlorethylene is insoluble in water, but it mixes freely with alcohol, benzene, acetone, and other organic solvents. Addition of water causes it to separate from alcohol or acetone mixtures, and its use in place of benzene has been advocated for the preparation of absolute alcohol by distillation.

Trichlorethylene is stable in air, but exposure to strong light causes decomposition to take place. The liquid does not attack common metals, although it appears to facilitate the rusting of iron. It has rapidly found favour as a solvent for sulphur, phosphorus, fats, waxes, resins, caoutchouc, etc. Not only is it a good solvent for these substances, but it possesses the great advantage over the older solvents in being non-inflammable. In addition to this use in the extraction of various substances, the solvent has been successfully applied in processes of " chemical cleaning." It is readily recoverable, and owing to its relatively low vapour pressure there is not an excessive loss in its use.

An unexpected property of the vapour is its selective action upon the fifth cranial nerve, and this has led to its application in treatment of trifacial neuralgia. It is found to be not nearly so toxic as chloroform.

Although chemically an unsaturated compound, trichlorethylene reacts relatively slowly towards chlorine and bromine and with oxidising agents such as potassium permanganate.

Notes and News

The Nobel Prize for Physiology and Medicine for the year 1932 has been divided between Sir Charles Sherrington, past president of the Royal Society, and Prof. E. D. Adrian, Foulerton research professor of the Royal Society. The Prize for Chemistry has been awarded to Irving Langmuir, of the General Electric Company of America.

His Majesty the King has approved of the award of *Royal medals* by the President and Council of the Royal Society to Prof. R. Robinson, for his work in organic chemistry, and to Prof. E. Mellanby, for his work in dietetics. In addition, the following awards have been made: *Copley medal* to Dr. G. E. Hale, for his work on the sun's magnetic field; *Rumford medal* to Prof. F. Haber, for his work on the applications of thermodynamics to chemistry; *Davy medal* to Prof. R. Willstätter, for his work in organic chemistry; *Darwin medal* to Dr. C. E. Correns, for his work in genetics; *Buchanan medal* to Prof. T. Madsen, for his researches on immunity; *Hughes medal* to Dr. J. Chadwick, for his researches in radioactivity.

The Rudolf-Virchow medal of the Berlin Anthropological Society has been awarded to Prof. Karl Pearson, Director of the Galton Laboratory of Applied Statistics and Eugenics.

The de Morgan medal of the London Mathematical Society has been awarded to Bertrand Russell.

Prof. A. Fowler and Sir Clement Hindley have been appointed to be members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research in succession to Sir Alfred Ewing and Sir David Milne-Watson, who retire on completion of their term of office. Sir Harold Hartley has been appointed chairman of the Fuel Research Board and Dr. N. V. Sidgwick chairman of the Chemistry Board.

Sir C. V. Raman, F.R.S., has been appointed to succeed Dr. M. O. Forster, F.R.S., as director of the Indian Institute of Science at Bangalore.

Sir Frederick Gowland Hopkins has been elected president of the British Association for the year 1933. The annual meeting will be held at Leicester during the period September 6–13.

Mr. W. F. Higgins has been appointed secretary of the National Physical Laboratory in succession to Mr. F. J. Selby, who has retired.

Prof. J. A. Crowther, professor of physics in the University of Reading, has been elected honorary secretary of the Institute of Physics.

Dr. Harold Moore has been appointed director of the British Non-Ferrous Metals Research Association. Dr. H. S.

Hutton, the retiring director, has been chosen to occupy the Goldsmith chair of metallurgy at the University of Cambridge.

Mr. N. E. Mott has been elected to follow Prof. Lennard Jones as Melville Wills professor of theoretical physics in the University of Bristol.

We have noted with great regret the announcement of the death of the following well-known workers in science during the past quarter: Mrs. G. P. Bidder (Marion Greenwood), physiologist; Sir Dugald Clerk, the internal combustion engine expert; Prof. Chaston Chapman, F.R.S., organic chemist; Sir William Clegg, chairman of the Applied Science Department of the University of Sheffield; Mr. Edwin Edser, the well-known author of textbooks of physics; Dr. W. Garnett, mathematician; Prof. K. von Goebel, For.Mem.R.S., botanist; Prof. T. Gray, technical chemist; Dr. F. H. Hatch, metallurgist; Prof. O. D. Kellogg, of Harvard, mathematician; Sir Bernard Mallett; Prof. W. H. Sherzer, of Michigan, geologist; Dr. T. H. C. Stevenson, statistician; Prof. W. Stirling, physiologist; Dr. J. Stuart Thomson, zoologist; Sir Everard im Thurm, anthropologist; Mr. H. G., Watkins, arctic explorer; Prof. Max Wolf, of Heidelberg, astronomer.

The annual meeting of the Science Masters' Association will be held in the University of Bristol during the period January 3–6.

The Common Council of the Corporation of the City of London has granted a sum of £100,000, payable in ten annual instalments, to the University of London in aid of the new building in Bloomsbury. The gift will be used to meet part of the cost of the Great Hall which is to be identified with the City in some distinctive manner.

The intimate relationship between chemistry and physics brought about by recent developments in mathematical physics has already produced in England the remarkable spectacle of a professor vacating the chair of theoretical physics in one university in order to occupy a chair of inorganic chemistry in another. Now, from the United States, comes the statement that the first important act of the newly formed Institute of Physics will be the publication of a *Journal of Chemical Physics.* The new *Journal* is designed to satisfy the need for a medium to provide publicity for papers too chemical in character for the pages of the *Physical Review* and too mathematical for a journal of physical chemistry.

The future of the Shirley Institute, the research station of the Cotton Research Association, is, it appears, imperilled by the coming exhaustion of the Government grant of £1,000,000 intended to tide the Association over its first difficult years.

The Institute costs £65,000 per annum to run, and the enthusiasm of the 1,200 members of the Association provides only £25,000! The Director of the Institute states that his staff is largely occupied with research on current problems; that he could usefully employ 400 people instead of the 200 now working under his control, and that there is very little time for work of a fundamental character. From these circumstances it would appear that the industry is by no means unappreciative of the results of scientific research provided it can get them at the expense of the taxpayer.

The Cambridge University Press announces the appearance of the second volume of Sir J. J. Thomson's and Prof. G. P. Thomson's book on the *Conduction of Electricity through Gases*, the second volume of Simonsen's book on the *Terpenes*, a book by Daynes on *Gas Analysis by Measurement of Thermal Conductivity*, and a new volume of the *Cambridge Mathematical Tracts*, by A. E. Ingham, entitled *Distribution of Prime Numbers*.

Miscellaneous Publication No. 118 of the U.S. Bureau of Standards contains a compilation, by T. Martin Lowry, of the data obtained before January 1, 1924, relating to the optical rotation of liquids and its variation with wavelength, temperature, solvent, and concentration. The tables were prepared for the International Critical Tables, but only the values for the common sugars and for common solvents at ordinary temperatures were included therein. The tables now published occupy some 95 pages of close type, and there are 232 references.

We have received the first volume of the *Bulletin of the Academy of Sciences of the United Provinces*, India. The Academy owes its existence to the enthusiasm of Prof. M. N. Saha, of Allahabad, and the generosity of the Government of the United Provinces, which provided a sum of 4,000 rupees to meet the initial expenses. The meeting of the Indian Science Congress in Allahabad in January 1930 provided an opportunity for discussion of the preliminary details. The Council met for the first time in January 1931, and the first ordinary meeting was held a month later. The *Bulletin* contains 27 papers on different branches of science, President Saha's inaugural address, a financial statement, and a list of members. The printing leaves little to be desired, even when judged by European standards, but some of the papers would have been the better for a little editorial attention. The price at which the *Bulletin* is to be sold is not stated, an unfortunate omission, for it will be wanted in all science libraries.

The *Bell Laboratories Record* for October 1932 contains an interesting account of the solder used for wiped joints on cables. As a result of many tests it has been found that an alloy of 38 per cent. tin and 62 per cent. lead is definitely

better than any others, though another, containing 9 per cent. cadmium, 24 per cent. tin, and 67 per cent. lead, was tried with promising results when the relative prices of these metals made the use of cadmium desirable. Small proportions of impurities have very deleterious results. Thus, more than 0·3 per cent. of antimony decreases the cohesiveness of the solder and shortens the plastic period during which working is possible. More than 0·005 per cent. of zinc produces a lumpy wiping material, but the presence of copper up to 0·1 per cent. is not objectionable. Bismuth is limited to 0·10 per cent., as its presence lowers the freezing-point, and thus prolongs the plastic period unnecessarily.

The *Bureau of Standards Journal of Research*, September 1932, contains an account of a new determination of the atomic weight of osmium, by R. Gilchrist. This element was first identified by Tennant in 1804, and twenty-four years afterwards Berzelius, by analysing potassium chloro-osmate (K_2OsCl_6), found for its atomic weight the value 198·94. In 1891 Seubert obtained values ranging from 190·27 to 192·22, and his results have been used as a basis for the value of the atomic weight given in the International Table. In 1912 Seigbold obtained 191·09 and 189·33. Gilchrist used ammonium chloro-osmate and ammonium bromo-osmate. He used osmium from different sources, varied his balances and weights, and took the utmost care in experimentation. His values are 191·53, 191·53, 191·55, and 191·61, with a weighted mean of 191·55.

The same issue of the *Journal* contains an account of an investigation by Meggers and Kiess of the infra-red arc spectra of titanium, iron, cobalt, nickel, and zirconium—the first instalment of an already-completed survey of fifty elements. The work has been made possible by the discovery of a new infra-red sensitiser, called xenocyanine, in the Eastman Kodak research laboratories. Fifteen years ago the best infra-red sensitiser available was dicyanin. Photographic plates bathed in this had a maximum sensitivity at 7,000A, but strong lines between 9,000A and 10,000A could be photographed with very long exposures. Another sensitiser, neocyanine, discovered in 1926, had a maximum effect at 8,100A, but did not extend the range appreciably. Xenocyanine covers the range 8,000A to 11,000A with a maximum at 9,600A ; it has in addition an extraordinary speed, permitting exposures from 100 to 1,000 times smaller than those previously possible in the interval 9,000–10,000A. The infra-red photographs which were such a notable feature of the illustrated papers in 1932 were obtained on plates soaked in this dye.

The *eupathescope* is a new instrument devised by Mr. A. F. Dufton, of the Building Research Station, to measure how much "colder it is now that the sun has gone," or "warmer round the

corner out of the wind." It actually measures the *equivalent temperature* of a room or any other environment. This is defined as the temperature of a uniform temperature enclosure in which, in still air, a sizable black body at 75° F. would lose heat at the same rate as it does in the environment. The instrument is described in a paper entitled *The equivalent temperature of a room and its measurement*, published by H.M. Stationery Office, (price *6d.*). Another pamphlet, issued at the same price, describes the sources, preparation, and applications of lithium. Until recently this metal was employed only in the form of its salts which were used chiefly in the treatment of rheumatism, but lately many other applications have been discovered. The metal is used both as a constituent of light alloys and as an agent for hardening aluminium and lead ; the hydroxide is used in the manufacture of alkaline accumulators, and other compounds are employed in the glass, ceramic, and enamelling industries.

The July issue of the *Journal of the Franklin Institute* contains a very interesting paper by Thomas D. Cope dealing with an early experiment on diffraction. It appears that one F. Hopkinson, of Philadelphia, wrote to David Rittenhouse on March 16, 1785, asking him to explain the curious colour fringes observed when a street lamp is viewed through a handkerchief held close to the eye. Rittenhouse was very intrigued with the phenomenon, and ultimately constructed a grating about half an inch square by laying hairs $\frac{1}{180}$ inch thick in the threads of fine screws of pitch $\frac{1}{106}$ inch which he cut from brass wire. Unfortunately, he complicated matters by using two sets of hairs at right angles set in four screws. Nevertheless, he was able to observe six orders of spectra, and with the help of a "prismatic telescope," lent to him by Dr. Franklin, measured their separation. He noted also that the order of the colours is the reverse of that given by Newton's prism. Interpretation of the results was of course impossible at the time, but Mr. Cope finds that his data give 6,200A and 4,600A as the wavelengths of red and blue light. The letters containing this remarkable anticipation of Fraunhofer's work were printed in the *Transactions of the American Philosophical Society* for 1786.

The recent announcement of the commercial agreements made at Ottawa lends special interest to two monographs of the *Australian Council for Scientific and Industrial Research* (Pamphlets No. 27 and 28, Melbourne, 1932). The animal industry of Australia is scientifically studying methods by which its trade with Britain may be expanded.

The development of Australia, north of the 19th parallel of latitude, has been seriously retarded owing to the poverty of its cattle husbandry. Geography and the cattle tick, the

transmitter of redwater fever, are the two influences adversely affecting the industry in tropical Australia ; of the two, the cattle tick is the more serious. The methods of eradicating the tick so successfully applied in the southern U.S.A. are not practicable in tropical Australia, consequently her problem is to find a breed of cattle which, (1) is naturally immune to tick-borne disease, (2) can thrive under her geographical conditions, and (3) will, as frozen meat, satisfy the criteria of the English market.

The Zebu or Brahman cattle (*Bos indicus*) satisfy the first two conditions, but they are unsatisfactory for meat and milk production. Conversely the first-class meat-producing British breeds rapidly decline in the tropics, and possess no immunity to tick-borne disease. Mr. R. B. Kelly, B.V.Sc., having studied the conditions of the meat industry on the Gulf of Mexico littoral, finds the solution of the problem in the production of a hybrid British-Zebu cattle by rigid selection under the control of the Commonwealth Government.

Further research will be required before Mr. Kelly's recommendation can be accepted with safety. For example, the half-bred British-Zebu under American conditions possesses a natural immunity to tick-borne disease, but its meat is of inferior quality ; on the other hand, to obtain a good quality beef the Zebu blood in the hybrid must be diluted to at least one-sixth or one-eighth, at which point the immunity appears to be lost. Experiments on the lines suggested by Mr. Kelly, if carried out by the Australian Government, are of immense importance in the economic development of the tropical lands in the British Empire.

In pamphlet No. 28 Mr. Kelly surveys the means of expanding Australia's pig export trade with England, which is her only potentially large overseas market. He recommends adjustments in the breeding and feeding of native stock for the production of a bacon pig, of which extensive exports (in the frozen carcase) could be accepted by the English bacon market.

To those who anticipate independence of foreign supplies for our Empire's basic foodstuffs, there is much encouragement in the biological research conducted in Australia.

REVIEWS

MATHEMATICS.

The Queen of the Sciences. By E. T. BELL, Ph.D., Professor of Mathematics in the California Institute of Technology. [Pp. 138, with 9 figures in the text.] (Baltimore: The Williams & Wilkins Co. London: Ballière, Tindall & Cox, 1931. Price 5*s*. 6*d*. net.)

CHARLES KINGSLEY left it on record that he read J. S. Mill's tract *On Liberty* at a sitting, and rose feeling a better man. I can say that I read E. T. Bell's little book from cover to cover without a break, and enjoyed every page of it. It more than compensated me for the hours lost on some very dull novels. Incidentally I found only three misprints, none of which was of the slightest importance.

It is a charming little book, instinct with true mathematical feeling, full of common sense, and an excellent antidote to the rhetorical nonsense that speaks of the Great Architect of the Universe being a pure mathematician. D. G. Rossetti said that the Pre-Raphaelite school of painters took as their watchword, "death to slosh." A little crude, perhaps, coming from the brother of the ethereal Christina; but the spirit of it might well be taken over by present-day mathematicians.

The fields of knowledge opened up by mathematicians during the past century are so vast as to break the heart of any who hopes to cover them all. None of us can hope to master more than a small corner. This should make us all the more grateful to those who indicate the lie of the land elsewhere. Here we have an eminently readable little book that performs the task admirably and succinctly. Its import can be grasped by physicists, chemists, engineers, and anybody anxious to improve his mind. It should find a place in the library of every school above the elementary, and in public libraries as well.

The work is excellently produced. The scarlet binding, with its silver label bearing black letters, is most attractive. The price is reasonable and the size is convenient for slipping into the coat pocket for a train journey. I offer the author my congratulations.

F. E. RELTON.

Foundations of the Theory of Algebraic Numbers. By Prof. HARRIS HANCOCK, Ph.D., D.Sc. Vol. I. [Pp. xxvi + 602.] (New York: The Macmillan Company, 1931. Price 8 dollars.)

THIS is the first and introductory volume of a large and detailed treatise on the theory of algebraic numbers. The volume opens with an account of the general notion of realms of rationality and of algebraic realms in particular, and passes on to discuss algebraic integers. The problem of the factorisation of an algebraic integer then leads to the core of the theory, namely, Kummer's ideal numbers, Dedekind's moduls and ideals, and Kronecker's modular systems. The author then considers the quadratic law of reciprocity, gives a more detailed treatment of quadratic and cubic realms, and a geometric presentation of ideals.

The method of exposition of this difficult subject is particularly clear. There is a good index and abundant references to the history and literature of the subject. But in spite of this one has the uneasy feeling that one cannot see the wood for the trees. The one guiding principle, which would have shed a flood of light on the subject—the theory of groups and algebras—is studiously avoided. The way in which these and allied concepts can be used to simplify and condense the theory of moduls and ideals is well shown in van der Waerden's *Moderne Algebra*. In fact, the author has failed to make use of a great opportunity for bringing group methods before the English-speaking world.

G. T.

An Introduction to the Theory of Canonical Matrices. By H. W. Turnbull, M.A., F.R.S., and A. C. Aitken, D.Sc. [Pp. xiii + 192.] (London: Blackie & Son, 1932. Price 17*s.* 6*d.* net.)

This book gives an admirably simple account of the various ways in which matrices of finite order can be reduced to canonical form under the more important types of transformation. Although the work serves as a sequel to *The Theory of Determinants, Matrices and Invariants* by Turnbull, the inclusion of an introductory chapter giving the necessary fundamental definitions and properties makes it effectively independent and self-contained. The subject is introduced by the elementary transformations which are involved in the standard processes for the reduction of a matrix preparatory to the evaluation of its determinant, and by the translation into matrix form of the process for determining the highest common factor of two polynomials (Chapter II). Chapter III deals in a general manner with the canonical reduction of λ-matrices, and the succeeding chapter classifies the types of sub-groups of the general group of transformations, $B = PAQ$, of the matrix A. The next four chapters examine these types of transformation in detail. Chapter IX considers the canonical reduction of pencils of matrices, $\Lambda = \lambda A + \mu B$. The concluding chapters apply the general theory to the solution of linear matrix equations and to problems of vibrations and mathematical statistics.

This book is enriched with historical notes, numerous illustrative examples, and a good index. Prospective readers should not be misled by the publisher's announcement on the dust-cover, for the theory expounded in this work has little bearing on quantum mechanics. Two further criticisms may be advanced, namely, that it seems a pity that the theory given here is not related to the theory of the representation of groups. Also the restriction to matrices of finite order is a severe limitation. With these reservations the book may be warmly recommended.

G. T.

Foundations of Point Set Theory. By R. L. Moore. [Pp. v + 486.] (American Mathematical Society Colloquium Publications. Vol. xiii, 1932. Price $5.)

It has been well said that the duty of the philosopher is to justify the intuitions of the plain man, and it is none the less true that it is the duty of the mathematician to justify the intuitions of the physicist. In particular, it is the task of topology to provide a rational basis for our spatial intuitions.

The logical account of any branch of mathematics must begin with undefined notions and unproved propositions, and, in topology, perhaps the most difficult part of the subject is the elucidation of these fundamentals. The great advantage of this volume is its careful analysis of the structure of the subject and the clarity with which it expounds the relation of each topological theorem to the set of definitions and axioms which form the basis of the subject. In fact, the present work is, in effect, an anatomical dissection of

topology revealing the skeleton of the subject, and perhaps suggesting the inevitable query, "Can these dry bones live?"

It is, of course, an inevitable characteristic of a treatise of this description that the early chapters are highly abstract in character, and that they deal with spaces which bear only a shadowy resemblance to the spaces utilised in mathematical physics, such as Euclidian spaces of three or any finite number of dimensions and the Hilbertian spaces of modern quantum theory. It is impossible to give in a short review an adequate account of the 500 pages of closely reasoned argument which compose the present work. There are, however, two points upon which this book is open to serious criticism.

In the first place, the study of the book is made unnecessarily difficult by the fact that the whole subject is expounded *more geometrico*. There is a most impressive array of definitions, axioms, and theorems, but no attempt has been made to show how the fundamental ideas and principles have actually been formed by abstraction and induction from the simple types of space mentioned above. For example: the first axiom (labelled "axiom O"), runs as follows: "Every region is a point set"; but there is nothing whatever to give the reader any idea what sort of entity a region may be. The only indication of the nature of a region is incidentally provided by the definition of the "boundary" of a point set M as the set of points X, such that every region that contains X contains at least one point of M and at least one point that does not belong to M. It would have helped the reader very much if some simple illustrations of a region had been given.

Again, the second axiom (labelled "axiom 1"), asserts the existence of a certain sequence of point sets possessing an array of properties which occupies no less than twelve lines of type. This is, perhaps, hardly the kind of axiom which one would expect to find as part of the basis of topology, but it may, nevertheless, be just as indispensable as Zermelo's axiom in the theory of numbers. The most casual reader cannot fail to remark that such an intricate assumption as "axiom 1" must be the outcome of a lengthy series of investigations into this subject. The rule that phylogeny should be a recapitulation of ontogeny holds in the realm of education no less than in biological science, and the historical approach to a subject is usually the best. In this case "axiom 1" has been robbed of most of its significance by the suppression of the history of its formulation.

In the second place, the author has not given a complete list of the undefined notions peculiar to the subject of topology. According to the introduction, the only undefined notions are "Point" and "Region," but on the first page of chapter 1 there appears a third notion which should certainly be included in this list. This is the notion of "inclusion," which expresses the relation of a region to a point. It is particularly unfortunate that the undefinable character of the relation of inclusion is not recognised in this treatise, for it appears from Whitehead's theory of Extensive Abstraction that a point can actually be defined in terms of a region and of inclusion.

These criticisms of the mode of exposition adopted by the author do not of course detract from the value of the matter contained in this monumental treatise. The book is enriched with a twenty-page Bibliography, and a glossary of the technical terms (*e.g.* cactoid, graphatomic subset, webless continuum), in which American topology seems to be especially rich.

G. T.

Differential Equations from the Algebraic Standpoint. By J. F. Ritt. [Pp. x + 172.] (American Mathematical Society Colloquium Publications. Vol. xiv, 1932. Price $2.50.)

There is a remarkable contrast between the theory of systems of algebraic equations and the theory of systems of differential equations. The theory of algebraic elimination and of algebraic reducibility is already classical, but the

corresponding theory of systems of differential equations has so far hardly been touched upon, even in Forsyth's great treatise. The object of this book is to develop the algebraic theory of systems of differential equations.

The central problem of the theory is that of the reducibility of systems of differential equations. It is shown here that any system of differential equations, finite or infinite in number, in a finite number of unknown functions, is composed of a finite number of irreducible systems. Furthermore, the author gives a method involving differentiation and rational operations for decomposing a finite system into irreducible systems, and for constructing resolvents which effectively determine the general solutions of irreducible systems. The last chapter extends the theory to systems of partial differential equations.

Only a few examples are given by the author, and these can all be studied by the light of nature without the aid of the elaborate theory developed in this book. It is remarkable that no example is given of a system with more than one equation. Such examples are, however, easily constructed, and the following problem will serve to illustrate the theory.

If u, v, and x are rectangular Cartesian co-ordinates, the general equations to a system of straight lines in space are :

$$\begin{aligned} u &= u_1 x + f(u_1, v_1), \\ v &= v_1 x + g(u_1, v_1), \end{aligned} \qquad \text{(A)}$$

where $u_n = d^n u/dx^n$,. . . etc. These generalised Clairaut equations lead on differentiation to the following relations:

$$\begin{aligned} 0 &= u_2(x + \partial f/\partial u_1) + v_2 \partial f/\partial v_1, \\ 0 &= v_2(x + \partial g/\partial v_1) + u_2 \partial f/\partial u_1, \end{aligned}$$

whence, either $u_2 = 0$ and $v_2 = 0$, (B)

or $$x_2 + x(\partial f/\partial u_1 + \partial g/\partial v_1) + \partial(f,g)/\partial(u_1,v_1) = 0. \qquad \text{(C)}$$

Here the original, reducible system of equations (A) is composed of the two irreducible systems, represented by (A) + (B), and (A) + (C) respectively.

The great value of this work is that it enables us to dispense with the assumption that a given system of differential equations can be reduced to a canonical form. Most existence theorems begin with the statement, " Let the given system of equations be solved for such and such derivatives. Unfortunately, the actual solution is usually impracticable. In addition to this the limitations imposed by the use of the implicit function theorem and the impossibility of preventing the entrance of extraneous solutions during the process of elimination exemplify the inadequacy of the classical theory. A discussion of systems of differential equations from the algebraic standpoint was an evident necessity, and the present monograph gives an admirable account of what has been done in this subject which has been created and developed almost entirely by the author of this book.

G. T.

ASTRONOMY

A Textbook of Practical Astronomy. By JASON J. NASSAU. [Pp. x + 226, with numerous illustrations and diagrams.] (London: McGraw-Hill Publishing Co., 1932. Price 18*s*. net.)

THIS textbook can be heartily recommended, not only to the students in civil engineering for whom it is primarily intended, but also to anyone who wishes to grasp the principles and methods of the determination of Time, Latitude and Azimuth. The descriptions of the instruments and the explanations of the methods of their employment are clear and concise, and the necessary adjustments, the corrections and the errors are treated adequately

and intelligibly. Prof. Nassau is an experienced teacher, and evidently knows well how to guide his students through their difficulties and over their pitfalls. Numerous illustrative examples are fully worked out which, together with the forms for recording the observations and for making the computations, will be found of great service, and the book abounds in practical hints, many elementary, but all useful. Proofs are given for the mathematical formulæ employed with the single exception of those of the spherical triangle, and it would surely have been worth while to devote a little space to these in order to make the student sound in his fundamentals and independent of mere assumptions. The price of the book is probably influenced by the adverse rate of exchange, but it seems high for a small volume of some 220 pages. With these minor criticisms, the reviewer can give the book whole-hearted praise. It is completed by a useful set of tables, four star maps and an adequate index.

R. W. Wrigley.

PHYSICS

Intermediate Physics. By C. J. Smith, Ph.D., M.Sc., A.R.C.S. [Pp. v + 650, with illustrations and diagrams, examples and answers.] (London: Edward Arnold, 1932. Price 14s. net.)

The tail must continue to follow the head, and Dr. Smith's textbook is an excellent example of this truth. There is nothing restful in the progress of any scientific subject; some of the information gained by those at the growing points must eventually come down and become common knowledge. Those whose duty it is to frame syllabuses know how hopeless the task is to keep examiners to their promises. Any good teacher or examiner possesses intuition of the standard of knowledge that can be expected from a given group of pupils. The assessment of this standard must be made in relation to the current and ever-increasing knowledge of the subject.

The most promising movement in elementary physics is towards simplification now that the methods of the calculus are commonplace at this stage. It would be a hopeless task to endeavour to include for due consideration every phenomenon offered by nature. We are hoping that this diversity is not so great as it has been our custom to imagine, and even in Intermediate teaching a commencement should be made in valuable generalisation.

Dr. Smith devotes about 108 pages to Properties of Matter, 130 to Heat, 150 to Optics, 50 to Acoustics, and 200 to Electricity and Magnetism. This is a very fair division. In the first section, apart from the ordinary mechanics, such subjects as diffusion, high vacua, surface tension, viscosity, and elasticity are dealt with. Even though there is nothing in the index to indicate that viscosity has been considered, yet in the text the definition of the coefficient is adequate, and the standard methods for determining viscosity are described. However laudable it is to introduce in its own place an illustration of a petrol pump as a harmless example of a suction pump, it is to be doubted if a description of the cup and ball viscometer will add anything to an Intermediate student's knowledge of the principles of physics. The section on Heat is enriched with many new diagrams that have not appeared before in an elementary textbook. The student is given the advantage of first-hand knowledge of the standard work on the subject of the late Prof. Callendar. The optical section is illustrated with a set of exceptionally clear diagrams. The elementary treatment of geometrical optics can become very cumbersome, but the author has covered the ground clearly and concisely. Perhaps a little attention might have been given to colour vision, and the direction of the light across the retina in Fig. 288 should be marked. In this section the introduction of the wave theory, the diffraction grating, and the sagittal method are merely signs of changing times. The section on Acoustics is more ordinary; this is more surprising in view of the remarkable develop-

ments that have taken place in this science in recent years. Intermediate students would be just as interested in a "talking picture" as in an organ pipe or siren.

The important subject of Magnetism and Electricity is covered in the order magnetism, electrostatics, and current electricity. An excellent treatment of the subject of magnetism and a fine set of diagrams is marred a little by the absence of arrows indicating the direction of the lines of force. In dealing with the magnetic effects of a current circuit, it is pleasing to see the so-called law of Biot and Savart subordinated to the far more general and valuable idea of the equivalence of a current circuit and a magnetic shell. It is to be hoped that all the rules for the mutual effect of magnetic fields and currents will eventually disappear except the right-hand screw convention. They are bad physics. The writer would find it much more difficult to remember the "rule" than to deduce the result from physical principles. The useful convention distinguishing inductive from non-inductive winding seems to have been dropped in this part of the book. It is true that inductive winding is more difficult to draw, but modern electrical diagrams would become meaningless if this convention were disregarded. The electron makes its appearance at the end of this section and even the Planck-Einstein photoelectric equation is introduced to strike the first real chord.

The work is excellently produced. It is, on the whole, a pleasing book to handle and strikes the teacher immediately as being the work of an author with a wide and balanced outlook on an ever-changing subject.

L. S.

Faraday and his Metallurgical Researches. By SIR ROBERT A. HADFIELD, Bt., D.Sc., D.Met., F.R.S., F.I.C., etc. [Pp. xx + 329, with 58 plates. 12 figures, and 27 tables.] (London: Chapman & Hall, 1931. Price 21s. net.)

ALTHOUGH Faraday is mostly remembered as the "Father of the Electrical Industry," he has, according to Sir Robert Hadfield, equal claim to be regarded as the "Pioneer of Alloy Steels." From 1819 to 1824 Faraday carried out a detailed investigation of steel and its alloys, this being the first research of any considerable magnitude undertaken by him. From 1824 onwards he was exclusively concerned with other problems; and in 1863, when his memory had begun to fail, he could not recollect what had become of the alloy specimens prepared forty years earlier. Posterity, too, largely forgot the work that had claimed five years of Faraday's thought and labour; and even Bence Jones wrote of it as having "ended in nothing" and "proved of no lasting value."

Fortunately, seventy-nine specimens of steel alloys prepared by Faraday were recently found at the Royal Institution in a box labelled "Steel and Alloys"—"Faraday." By permission of the Managers of the Royal Institution, Sir Robert Hadfield has made a complete analysis of these specimens at the Hadfield Research Laboratories, Sheffield. Other specimens were examined at the same time, some provided by the courtesy of the Director of the Science Museum and others obtained from private sources.

The broad-minded attitude of the authorities mentioned, Sir Robert Hadfield justly remarks, "might well be copied by all who are in charge of relics of the past, for without it the achievements of our predecessors cannot be accurately assessed and much knowledge may be lost." This book should do much to make such an attitude more general; and, on this matter, a few facts are worth quoting. Of the original 3,741 grams of material, the total weight of the specimens examined, only 591 grams were used in the investigation, although 493 chemical analyses and 866 chemical, physical, and mechanical tests were carried out. The specimens thus remain comparatively intact and with their value unimpaired; and methods have been devised

that should make any such investigation much easier in the future, when, it is to be hoped, museum and other authorities will have learned that this does not involve the destruction of the objects in their care.

The results described here clearly show that Faraday was far in advance of his time and that there was neither the skill among the steelmakers to apply his results nor a commercial demand for such alloys as he had prepared. They show, too, that Faraday's work in this field "deserves to rank with his other better-known researches," since "he was, in fact, the first to conceive and put into effect the idea of a really comprehensive investigation of the possibility of alloying steel with various elements, followed by the examination of the properties of the alloys formed." The problem was so successfully attacked that Faraday may properly be regarded as the pioneer investigator of alloy steels. The work definitely received some industrial application, and certain of the alloys were made "in the large way" at Sheffield. But the death of Faraday's friend, Stodart, in 1823 severed the link between the laboratory and the workshop, and the research was abandoned, not, however, without Faraday's labours receiving considerable contemporary recognition in France and Russia.

Faraday records the use of sixteen elements as alloying materials, and it is interesting to find that Sir Robert Hadfield has detected twelve of these in the specimens examined, namely, carbon, chromium, nickel, copper, gold, iron, platinum, rhodium, palladium, silicon, silver, and sulphur. Those missing are iridium, osmium, titanium, and tin. Thus, although the specimens recovered can be only a few of many that Faraday prepared, they provide striking evidence of the comprehensive nature of his research.

The volume is splendidly illustrated with portraits, photomicrographs, etc. It is fortunate that this work, in itself a valuable contribution to the history of science, has been carried out by one who has devoted a lifetime to metallurgical research, and who, in proclaiming Faraday the "Pioneer of Alloy Steels," resigns a title that has long been his own by the verdict of his scientific contemporaries throughout the world.

"Union" on p. 16 should read "University." D. McKie.

National Research Council, Bulletin 84. Report of the Committee on Hydrodynamics. [Pp. 634.] (Washington D.C.: The National Research Council of the National Academy of Sciences, 1931. Price $4.50.)

This work is a veritable encyclopædia on the history and present state of our knowledge of the motion of fluids. It is divided into four parts. Part I extends to about one hundred and fifty pages, and summarises classical hydrodynamics and the physics of fluids. Part II, somewhat longer, is concerned with the motion of an incompressible viscous liquid. Part III comprises a hundred and sixty pages and discusses turbulent flow. Part IV, with rather less than a hundred pages, deals with compressible fluids.

The number of references is colossal. Throughout the body of the work they are placed in juxtaposition to the topics discussed, a pleasing feature, in that it saves continually turning to the end of the chapter. Yet at the end of the book there are no less than eighteen pages of additional references, all carefully arranged in accordance with the chapters to which they relate. Further, there are twenty pages of author index and nine pages of subject index.

This is no hasty compilation; it has taken years to produce. The thoroughness with which the work has been done is ample evidence of the assiduity which the authors have brought to bear on their task. I have repeatedly tested it by consultation on matters of specialised interest, and on papers not widely read. Each test has served to deepen my impression of its excellence. For the most part it is the work of H. Bateman, that excellent

mathematician and producer of beautiful books, and it is in every way what one would expect of him. The numerous diagrams are well done; the mathematical printing has a subtle suggestion of affluence that makes contemplation a pleasure in itself.

Whoever is interested in the mathematical discussion of fluid motion would do well to get this bulletin; whoever contemplates doing research in this subject should certainly have access to it; and whoever acquires the book will do well to invest the few shillings that it will cost to have it stoutly bound.

F. E. Relton.

Electrons and Waves. An Introduction to Atomic Physics. By H. Stanley Allen, F.R.S., Professor of Natural Philosophy in the University of St. Andrews. [Pp. x + 336.] (London: Macmillan & Co., 1932. Price 8*s*. 6*d*. net.)

This neat little book is in the main intended for readers who have not specialised in physics. It presents, in a manner which shows much evidence of clear thought and careful selection of material, an outline of the main facts and trends of modern physics. It is well printed and effectively illustrated, and the scholarly atmosphere which pervades its pages is bound to appeal to the general reader.

A selection of books for further reading is given in an appendix. On the whole, the selection is very good, but one or two books have been included which might quite well have been omitted. This, however, is a very small matter, and we wish the work every success.

L. F. B.

Snow Crystals. By W. A. Bentley and W. J. Humphreys. [Pp. ix + 227, with plates.] (London: McGraw-Hill Publishing Co., 1931. Price £3 net.)

This is a beautiful book, a source of wonder and delight, a treasure to both science and art. Merely to turn its pages inspires the liveliest pleasure, till one finally stands amazed once more at the infinite cunning of Nature's handiwork.

It is a record of fifty years' work on the photomicrography of snow and ice crystals, carried out with admirable craftsmanship and enviable patience by Mr. W. A. Bentley of Jericho, Vermont. The volume contains some twenty-five hundred different photographs, charmingly reproduced against a black background and arranged in order of increasing complexity—but it is impossible to do justice to them, or to invoke in the reader of this review even a faint reflection of the emotions they call forth. They are exquisite, fascinating, bewildering, at once a wordless treatise on design and the experimental basis of the crystallography of ice.

Looking at these photographs with the eye of a structural crystallographer, how strong the impression almost of ignorance! We have deduced the atomic arrangement in the hexagonal form of ice, but how remote it seems from even the simplest of these elaborate patterns! How much more work still remains to be done to interpret completely only one of these thousands of manifestations of the architecture of solid water!

All but about thirty pages of *Snow Crystals* are devoted to the reproduction of Mr. Bentley's actual photomicrographs. The arrangement and brief introduction are due to Dr. W. J. Humphreys of the American Meteorological Society. The financial difficulties of the publication have been overcome by the generosity of an unnamed benefactor who, together with those already mentioned and the McGraw-Hill Publishing Company, has thus laid us all, young and old alike, under a debt of the sincerest gratitude.

W. T. Astbury.

Physikalisch-Chemisches Taschenbuch. Unter Mitwirkung zahlreicher Fachgenossen. Herausgegeben von C. DRUCKER und E. PROSKAUER. Band I. [Pp. viii + 546, mit 292 figuren und 81 tabellen.] (Leipzig: Akademische Verlagsgesellschaft m.b.H., 1932. Price M. 27·50 brosch., M. 29 geb.)

THE book before us is the first volume of what should prove a popular and useful work. No indication is given of the number of volumes which make up the complete work, although some reference is made to a second volume. Since the first volume contains four sections, respectively dealing with the structure of matter, optics, electricity, and magnetism, it would appear that the work should be complete in two volumes. The material collected in the first volume has been chosen mainly because of its more immediate importance in current thought.

The purpose of the work is to provide, in a small space, definitions of all the important physical quantities, short descriptions of the methods by which these are measured and brief indications of any cognate theories. It is really intended to be a kind of guide-book. Consequently, it will be judged by the ease with which a reader may obtain a preliminary survey of a principle of physics or of a phenomenon in which he is interested at the moment, and by the completeness, or, in many cases the choice, of works to which he is advised to refer for further details.

Perhaps this may be made more clear by considering the shortest section, on magnetism, contributed by L. C. Glaser. He gives a complete statement of the various definitions and units required in magnetism, and then outlines the more important methods of measurement of the properties of ferromagnetic and of weakly magnetic bodies. Incidentally, he stresses the magnetic potentiometer method for the determination of a hysteresis curve, devised by Rogowski and Steinhaus; he appears, however, to think that the instrument was discovered by them, whereas it was described many years ago by Chattock. Glaser then very briefly reviews the theories of diamagnetism, paramagnetism, and ferromagnetism, and his references appear fairly complete, although no reference is made to the work of Van Vleck. The section closes with some interesting tables of magnetic data.

Naturally, in such a book in the German tongue, suggestions for further reading in the more firmly established branches of physics are mainly confined to German publications. In the case of the less firmly established branches of physics, however, the references to original papers in English and German are well balanced and quite adequate. The book should be particularly helpful to chemists and physicists whose opportunities for the perusal of current periodicals are limited.

The reviewer feels that the work could be made even more helpful to all classes of reader if space were left for the insertion of further references at the end of each sub-section. It often happens that one reads an important paper on some branch of physics, of which one would desire to make a permanent note for future reference. The book before us is a most excellent place in which to enter such notes, and in this way it would be automatically kept more or less up-to-date We heartily commend the work and look forward to the appearance of the second volume.

L. F. B.

Müller-Pouillets Lehrbuch der Physik. 11 Auflage. Vierter Band-Erster Teil. Grundlagen der Lehre von der Elektrizität und dem Magnetismus. [Pp. xxii + 734, with 774 figures.] (Braunschweig: Vieweg & Sohn, 1932. Geh. M. 47·50, geb. M. 51.)

IT is very pleasing to record the appearance of the first part of the fourth volume of the eleventh edition of this well-known work, for it practically

marks the completion of the edition. Originally, the edition was planned by Eucken, Lummer, and Waetzmann, and we again express our regret that Lummer has not lived to see the work completed.

The fourth volume is clearly one of very wide range, and it is divided into four parts. The first two parts are concerned with those branches of electricity and magnetism which have not suffered very revolutionary changes since the appearance of the tenth edition. The remaining parts deal with what is generally, if vaguely, termed modern physics. This division appears to have been decided by Prof. Valentiner of Clausthal, who is mainly responsible for the first two parts.

He has divided the subject-matter of these two parts into five sections, which respectively cover the phenomena exhibited by constant electrical fields, constant electromagnetic fields, and slowly changing electromagnetic fields, electrical machinery, and high-frequency phenomena. The book before us deals with the first three of these sections.

Obviously, in the case of the eleventh edition of a standard work, the reviewer's task is mainly to note the steps which have been taken to bring the new edition up-to-date, and to make it better than its predecessor. Prof. Valentiner has certainly made some very important changes and additions.

He has, for example, given a much more complete treatment of the Maxwell theory than is to be found in the tenth edition. Moreover, he has described a large number of modern measuring instruments and methods of measurement. He has made an attempt to introduce some modern work on frictional electricity. He has not omitted some of the lesser-known phenomena, such as the Johnsen-Rahbek effect, which is briefly outlined, and of which a technical application is described.

The pedagogical value of the book is greatly increased by the inclusion of many illustrations of apparatus and experiments recently designed by Pohl and others. Considerable pains have been taken to emphasise changes in systems of units whenever they occur, and a table is given showing the factors to be employed in various formulæ when a change is made from one system of units to another. Presumably, some mention of Tolman's suggestions concerning units will be made later in the work, when the properties of the electron have been described.

A pleasing feature of the book is the section on the production of strong magnetic fields, where some very useful descriptions of modern electromagnets are given. It is realised, too, that in a book of this kind, hints on experimental procedure and technique are valuable, and such hints are frequently supplied.

The book is excellently printed and illustrated, and the references to original papers are very complete and show no marked bias in favour of German sources of information. It is a worthy addition to the literature of physics.

L. F. B.

Thermionic Emission. Department of Scientific and Industrial Research. Radio Research Special Report No. 11. [Pp. iv + 116.] (London: H.M. Stationery Office, 1932. Price 2*s*. 6*d*. net.)

On the advice of the Thermionics Committee, the Radio Research Board decided to compile a critical survey of the literature of thermionics with special reference to the filaments of thermionic valves. The necessary compilation has been carried out in a very able manner and embodied in this special report by Dr. W. S. Stiles.

The report represents a complete summary of all the major publications on the subject of thermionics up to December 1930. It is conveniently divided into nine sections, together with an extensive bibliography and an author index. Consequently, it is possible for a reader, interested, for example,

in the Schottky effect, to turn to the appropriate section and to peruse a well-ordered, concise account of all the outstanding papers on this effect. As the bibliography is arranged on the decimal system, the reader may insert his own and later references concerning the effect in their proper sequence.

The whole survey is extremely valuable and almost indispensable to new workers in this extensive field of research.

L. F. B.

CHEMISTRY.

An Introduction to Biochemistry. By RODGER J. WILLIAMS, Ph.D. [Pp. xiv + 501.] (London: Chapman & Hall, 1932. Price 21*s.*)

IN this book, Biochemistry is interpreted broadly as the study of organisms from the chemical point of view. The subject is thus a wide one, and to deal with it at all adequately within a volume of 500 pages is therefore a task of no small difficulty. The author is to be congratulated on his courage and his success.

After an introduction which outlines the scope of the book and the method of treatment, the six sections deal successively with: (1) the composition of organisms, (2) their nutritional requirements, (3) the chemical mechanism employed by organisms, (4) the metabolism of single cells, (5) the metabolism of green plants, and (6) the metabolism of mammals. An appendix gives practical details of suitable laboratory experiments for students, along with a brief survey of the literature of biochemistry. This volume makes no attempt to be exhaustive, but at the end of each chapter a list of references to more specialised articles is given, so that the student may supplement his knowledge by further reading. These references are on the whole well chosen, although a reader on this side of the Atlantic might perhaps judge them unduly weighted by articles of American origin. Other features of the book, *e.g.* spellings such as "color," "centered," "mollusk," also remind the reader of the nationality of the author; however, these are minor matters. An attractive feature is the emphasis laid on the unsolved state of many of the problems discussed, especially the more fundamental problems.

The reader is constantly reminded of how little we do know of the vital processes and the need and scope for further research.

The book is not, and does not pretend to be, an advanced manual for the specialised research worker, nor a cut-and-dry summary of facts suitable for examination cramming. It is, however, a book which should prove useful particularly to the man who, in his fourth year or after taking his degree in general chemistry, wishes an introductory account of the more specialised subject of biochemistry, or to the worker in some particular branch of applied chemistry who finds that a general knowledge of biochemistry would be helpful to him.

W. O. KERMACK.

Alcoholic Fermentation. By ARTHUR HARDEN, Ph.D., D.Sc., LL.D., F.R.S. Fourth Edition. [Pp. vii + 243.] (London: Longmans, Green & Co., 1932. Price 15*s.* net.)

THE nine years which have elapsed since the last edition of this monograph have been a period of considerable activity in the investigation of the problems connected with alcoholic fermentation; and although the author does not claim to give a complete account of the work published in this interval, he has nevertheless found it necessary to increase the size of the book by nearly fifty pages. The chapters which are chiefly concerned in this increase are those devoted to the function of phosphates in alcoholic fermentation and the chemical changes involved in fermentation. Since the discovery by Harden and Young of a hexosediphosphate in yeast juice fermentation, glucose, fructose, and trehalosemonophosphate have been isolated from such

fermentations and hexose mono- and di-phosphoric acids have been isolated from muscle, while a hexose monophosphoric acid has also been obtained by partial hydrolysis of hexose diphosphate. The methods of isolation and characterisation of these various substances are fully described and the various views on their function are also given. All those who are not actually engaged in work on fermentation, but wish to be kept informed as to the latest developments, will be grateful to the author for having selected the really essential points from an almost bewildering amount of literature, a list of which occupies thirty-eight pages at the end of the book.

P. H.

Ergebnisse der Enzymforschung. Herausgegeben von F. F. Nord und R. Weidenhagen. Vol. I. [Pp. xi + 377, with 63 figures.] (Leipzig: Akademische Verlagsgesellschaft m.b.H., 1932. Price 27 M. (unbound)).

This is a collection of essays by sixteen different authors written in English, French, or German. The editors in their preface state that they intend publishing from time to time a collection of such reports on various aspects of enzyme investigation; these reports are not intended to summarise the literature of their respective subjects, but to present special accounts of the work upon which the writers are themselves engaged. While it is not possible to give a complete list of the titles of the sixteen contributions, it should be stated that the subject has been treated on broad lines with due consideration of general principles; thus there are articles on Thermodynamics of Cell Reactions by Ellis Fulmer, on Signification des potentiels d'oxydo-réduction pour les reactions enzymatiques by René Wurmser, on Mechanismus der Enzymwirkung by A. Fodor, on Physikalisch-chemische Vorgänge bei Enzymreaktionen by F. F. Nord, while special aspects are catered for in articles on Proteolytische Enzyme des Tier und Pflanzenreiches by W. Grassmann, Bacterial Enzyme Reactions by J. H. Quastel, Crystalline Pepsin by John H. Northrop, Das Sauerstoffübertragende Ferment der Atmung by Albert Reid, and the Biochemistry of the Lower Fungi by Harold Raistrick. The volume, which is nicely produced and clearly printed, contains a mass of information which should be consulted by all who wish to obtain in easily accessible form authoritative accounts of the subjects dealt with.

P. H.

Sulphur Bacteria. A Monograph. By David Ellis, D.Sc. (Lond.), Ph.D. (Marburg), F.R.S.E. [Pp. ix + 261, with illustrations.] (London: Longmans, Green & Co., 1932. Price 21*s*. net.)

In this monograph there is presented for the first time a comprehensive account in English of the sulphur bacteria, a group which is interpreted by the author as embracing "only those organisms which oxidise H_2S to S, store the latter temporarily in their bodies and then oxidise it to—SO^4." Thus four classes of bacteria which are concerned with sulphur metabolism, but do not actually store sulphur at any time, are not included in the group. The four classes referred to are: (1) the Thiosulphate Bacteria, which oxidise thiosulphates; (2) the denitrifying Thiosulphate Bacteria, which oxidise thiosulphates, sulphites, sulphuretted hydrogen or sulphur to sulphates by means of oxygen obtained from the reduction of nitrates; (3) Sulphate-reducing Bacteria; and (4) Saprophytic Bacteria, which liberate sulphuretted hydrogen from the organic molecule.

Even with this limitation of the field the sulphur bacteria, as here defined, form a very extensive group which have occupied the attention of many workers in a number of different countries, as is to be expected from their wide geographical distribution. In spite of the amount of work carried out

there is a considerable divergence of opinion as to their metabolism. While under natural conditions sulphur bacteria are found in presence of quantities of organic matter, many authors regard organic matter as unessential to their development; while they may not assimilate organic matter as such, they must derive nourishment from the products of decomposition of such organic matter; while Bavendamm, from observations on pure cultures, came to the conclusion that under no circumstances is organic matter used as a source of nitrogen, the author points out that Bavendamm's cultures did not show the same healthy growths which characterise growths in nature, a remark which applies with equal force to his own observations on the growth of *Thioporphyra volutans* in a medium from which organic matter was excluded. With regard to carbon, Bavendamm in Holland and Skene in this country have shown that atmospheric carbon dioxide completely suffices for the carbon requirements of sulphur bacteria, but it has still to be proved that under other circumstances they are unable to make use of carbon in any other form of combination. Concerning the absorption of sulphuretted hydrogen and its function it is shown that this substance is not a food and that its conversion to sulphur does not liberate energy, and it is therefore suggested that it acts as an adjunct in the respiration process and is part of a mechanism for transferring energy from a less to a more available condition. While Winogradsky, Skene, and Bavendamm maintain that sulphuretted hydrogen is indispensable to the growth of the bacteria they examined, both Molisch and the present author have shown for different species of *Chromatium* that they could multiply in the complete absence of this gas. These facts indicate that the sulphur bacteria can derive energy in more than one way and the author suggests the term pleoenergism to indicate this in the same way as pleomorphism is used to express the tendency of the same organism to occur in more than one form, according to circumstances.

After devoting a chapter to the culture of sulphur bacteria the author reviews the various existing classifications associated with the names of Winogradsky, Molisch, Orla Jensen, and Buchanan, criticising each in turn, and finally proposes one of his own, which he follows in the systematic description which extends over four chapters. The basis of the classification is the division into the two groups of Colourless or *Leuco-Thiobacteria* and Coloured or *Rhodo-Thiobacteria*, while Molisch included in his classification only the latter group. A short chapter at the end of the book is devoted to the colouring matter of these bacteria. In addition there are chapters devoted to the Intimate Structure of the Cell, to Irritability, Influence of Light and Chemiotactic Phenomena, as well as to the mechanics of ciliary movement and the Phylogeny of the Sulphur Bacteria. It will be seen from what has been said that the subject has been dealt with in a comprehensive manner; the book is well produced and contains a number of very clear illustrations which add greatly to the value of a most interesting and instructive monograph.

P. H.

Introduction to Agricultural Biochemistry. By R. ADAMS DUTCHER, Professor of Agricultural and Biological Chemistry, and DENNIS E. HALEY, Professor of Soil and Phytochemistry. [Pp. x + 484.] (New York: John Wiley & Sons, 1932. Price 28*s*. net.)

As explained in the preface, this book is a development of lectures delivered to agricultural students over a period of nearly twenty years, and it must be admitted that such a course, if properly mastered, should form a valuable equipment to anyone intending to pursue an agricultural calling. It is, however, perhaps permissible to question whether some of the subjects dealt with can properly be called Biochemistry. A perusal of the book leaves the impression that rather too much has been included under one cover, with the

result that some sections have been unduly compressed. On the other hand, the authors state that they have endeavoured to emphasise the importance of scientific research and to impress upon the student that he should not accept all things as facts, but should realise that there are still many problems awaiting solution. The book is divided into three parts, of which the first is entitled General and Introductory; this opens with a chapter on the development of agricultural chemistry, and contains chapters on the carbohydrates, fats and proteins which follow more or less conventional lines, while in addition there are two well-written chapters on the chemistry of living matter and the physical state of matter which contain in concise form the essential points which a student should know. The second part, dealing with the Plant, is the largest of the three sections of the book; it opens with a chapter on Seed Germination, in which the various aspects of this phenomenon are set forth so as to present a clear picture of the whole question; then follows a useful account of the soil as regards its origin and composition, the availability of its nutrients, its physical properties and its biological processes. Other chapters deal with the atmosphere, insecticides and fungicides, etc., photosynthesis and respiration. The third part is devoted to the Animal; it contains chapters on the physiology of digestion, protein and carbohydrate metabolism, protein quality and vitamins, each of the five latter receiving a special chapter. The book contains much that is of interest and many valuable data in support of the statements made in the text, but the attempt to crowd so much information into a limited space has resulted in some of the accounts lacking in sufficient detail to be entirely clear to those not already familiar with the subject.

P. H.

Modern Methods in Quantitative Chemical Analysis. By A. D. MITCHELL and A. M. WARD. [Pp. x + 178.] (London: Longmans, Green & Co., 1932. Price 6s.)

DRS. MITCHELL and Ward have produced a very useful book which has made available at an almost negligible cost all the most valuable of the modern methods of quantitative inorganic analysis. The book, therefore, is a supplement to the large standard works on quantitative analysis which by reason of their size are inevitably some years behind the times.

A number of methods of wide application are discussed; for example, those depending on the formation of positive halogen ions, on the use of absorption indicators and on the "Reductor." These are followed by modern methods of estimation of some forty-four elements and twenty-four radicals and compounds, including a few organic substances such as urea and formaldehyde. Electro-metric methods have been excluded. The great majority of the processes described have been tested by the authors, who have introduced modifications where found desirable; full references are, however, given to the original literature. The work is therefore critical and no mere compilation, a most important consideration. As many of these methods have been devised to facilitate analytical work, it is difficult to see how any chemist can afford to be without this valuable reference book on his shelves. Apart from its obvious value to those engaged on analytical work, research workers in many fields will find it will help with some of the frequent analytical difficulties they encounter; students and teachers of analytical chemistry will find it of use to supplement the classical methods, some of which, perhaps, have a reputation founded more on antiquity than accuracy or convenience; while the theoretical ideas on which many of the methods depend must be of interest to all chemists who realise that accurate quantitative work is still the basis of their science.

O. L. B.

A Textbook of Organic Chemistry. By JULIUS SCHMIDT. English edition by H. GORDON RULE. Second edition, revised and enlarged. [Pp. xxiii + 843.] (London: Gurney & Jackson, 1932. Price 25s. net.)

THE appearance of a second edition of this work indicates that it has met a demand; this is not surprising, owing to its pronounced merits and the shortage of textbooks of organic chemistry in English which deal with the subject in more than an elementary manner. The book is clearly and interestingly written and has been brought up-to-date as regards the descriptive matter, but it treats the subject practically entirely on classical lines. This is no doubt desirable for elementary students, but does not justify the claim on the dust-cover that it is suitable as a routine textbook for honours students of chemistry. Though it would be impossible in a book of this kind to introduce electronic explanations of all the organic phenomena mentioned, this aspect of organic chemistry is so much in the mind now that a little more about it would have been an advantage; it hardly seems worth while to devote more than a page to Flürscheim's and Holleman's theories of benzene substitution and then give a number of references only to the electronic theories.

In dealing with a general textbook it is inevitable that the reviewer will apply the test of looking up subjects on which he has pronounced views on the method of treatment. In this rather severe ordeal the book is not disappointing. The treatment of stereo-chemistry is sound. The relation between optical isomerism and molecular asymmetry is clearly brought out, though it is perhaps not sufficiently emphasised that the type of compound with four dissimilar groups attached to a carbon atom is a special case of the general proposition. The geometrical isomerism of the oximes is given rather more space than it deserves in comparison with that of carbon compounds. The former is a complicated problem of less importance to undergraduates than a clear understanding of the simple cases of the maleinoid and fumaroid type. The cis- or trans-elimination or group migration in oximes and the problems of configuration are confusing to the student when no adequate discussion of the problem of the configuration and behaviour of maleic and fumaric acids is given. The old error which has been copied from textbook to textbook for years, that one isomeric aldoxime loses water more readily than the other, crops up once again.

In the account of melting-points, some qualification is needed of the statement that two substances are identical when a mixture of the two in any proportions has the same melting-point as either of the pure substances.

These, however, are minor criticisms; the book is excellently produced, contains much information attractively and accurately presented and can be warmly recommended as a textbook of descriptive organic chemistry.

O. L. B.

Chemical Encyclopædia. A Digest of Chemistry and its Industrial Applications. By C. T. KINGZETT, F.I.C., F.C.S., one of the original founders of the Institute of Chemistry. Fifth Edition. [Pp. viii + 1,014.] (London: Baillière, Tindall & Cox, 1932. Price 40s. net.)

FIRST published in 1919, this book has now attained to a fifth edition, which is sufficient proof that it supplies a want and has presumably justified the author's ambition—expressed in the preface to the third edition—"to popularise the study of chemistry and advance its applications to industry within the Empire." As a handy book of reference on quite a number of subjects or to explain trade names or trivial names of many products, it may be consulted in the first instance, and a number of the longer articles are quite well written, but the attempt, in these days, to condense an encyclopædia of chemistry into 1,000 odd pages is bound to invite criticism, and many

of the articles such as those on Force, Food, Vegetation, etc., taken at random, require to be read with discrimination. In many cases the substance of the article has been largely replaced by an ill-balanced medley of references to short articles from journals; in this respect the articles on biochemistry and X-rays stand out; it would be difficult, for example, from the latter to gather who were the chief contributors to our knowledge of X-ray spectra.

Organic Syntheses. Collective Volume I. Being a Revised Edition of Annual Volumes I-IX. [Pp. ix. + 564.] (New York: John Wiley & Sons, Inc., 1932. London: Chapman & Hall. Price 37*s*. 6*d*.)

To organic chemists the separate annual parts of *Organic Syntheses* have become familiar as the standard authority for the best methods of preparing the compounds they deal with. Starting in 1921, the eleventh volume was published in 1931, and now the editorial board have thought fit to republish the first nine volumes, having thoroughly revised the material contained in them. The 260-odd preparations have been arranged in alphabetical order, but for convenience of reference five different indexes furnished with thumb-index marks are provided. The first of these is a Type of Reaction Index, in which preparations are grouped under such headings as Halogenation, Oxidation, etc. This is followed by a Type of Compound Index, a Formula Index, of use in tracing compounds having more than one name, an Illustration Index, and a General Index. From the above it will be seen that no pains have been spared to make this a most valuable and easily used reference book. It is proposed that the next Collective Index shall comprise preparations already published, or about to be published, in Volumes X to XIX inclusive.

P. H.

An Introduction to the Scientific Study of the Soil. By NORMAN M. COMBER, D.Sc. (Lond.), A.R.C.S., F.I.C., Professor of Agricultural Chemistry in the University of Leeds. Second Edition. [Pp. 208.] (London: Edward Arnold & Co., 1932. Price 7*s*. 6*d*.)

THE first edition of this very handy little volume was published in 1927 and reviewed at the time in these columns. The scope and size of the book remain practically unaltered, but it has been brought up-to-date where necessary. The chief additions or alterations are concerned with Soil Microbiology, of which a somewhat fuller account is given, and with Mechanical Analysis—a subject which has been in a state of flux in recent years. Other additions are concerned with the water relations of soil, with special reference to capillarity, with Kappen's classification of soil acidity—a highly controversial subject—and with an account of the recent German methods of Neuberg and Mitscherlich respectively for determining manurial requirement of plants. The Short Appendix A on colloids has been recast, and the Appendix B on Surface Tension and capillarity has been removed. The little book may be recommended as a very readable and instructive summary of the subject which will serve admirably as an introduction for students of agriculture, horticulture, and of ecology.

P. H.

Soils. Their Origin, Constitution, and Classification. An Introduction to Pedology. By GILBERT WOODING ROBINSON, M.A., Professor of Agricultural Chemistry in the University College of North Wales, Bangor. [Pp. xiv + 390.] (London: Thomas Marby & Co., 1932. Price 20*s*. net.)

THE inclusion in the sub-title of the term Pedology is significant as a step in the direction of overcoming the reluctance of workers in this country to

accept this word for the study of the soil as a definite branch of natural philosophy. The increased interest in soil problems during recent years and the new outlook upon them, resulting largely from the work of the Russian School, has enlarged the scope of the subject to such an extent that the author has felt himself constrained only to attempt a general review of the subject, but it may be said at once that it is a very effective and comprehensive one. The opening chapter, entitled Introductory, sets forth with commendable clarity the scope and purpose of the "new" science and forms an effective refutation of the quotation from *Don Quixote* which the author modestly quotes against himself to the effect that he "propounds something and concludes nothing." The book is divided into nineteen chapters, of which the first eight are devoted to the origin, constitution, and properties of the soil; then follow six chapters dealing with a description of the chief soil groups of the world, while the next two chapters are concerned with the classification and geographical distribution of soils. The three remaining chapters deal with Soil Surveys, Soil Analysis, and the Interrelationships of Soils, Plant Growth, and Agriculture. The outlook of the book is quite definitely not utilitarian, and is perhaps best reflected by quoting the author's own words taken from the last chapter. "We have consciously refrained from presenting the problems of the soil from the standpoint of crop production . . . partly because a satisfactory apprehension of the nature of the contract between the soil and the living plant must be preceded by a thorough understanding of the constitution of the soil." There is much information to be found in these pages which cannot be found in any other book published in this country, and an unique feature is an attempt to review the soils of the world, thereby supplying a useful source of reference to the types met with in different countries. The book will be welcomed alike by geologists, botanists, and ecologists, as a valuable addition to the literature of soil science.

P. H.

The Heat-Treatment and Annealing of Aluminium and its Alloys. By N. F. BUDGEN. [Pp. xvii + 341, with 231 figures.] (London: Chapman and Hall, 1932. Price 25*s*. net.)

THE title of this book may appear redundant, as annealing is obviously a common type of heat-treatment, but the author has thought it advisable to include the term "Annealing" in the title because in the aluminium industry the general term "Heat-treatment" is commonly used in a restricted sense, being applied only to hardening and strengthening processes.

It is only about twenty years since the discovery was made that the strength of some aluminium alloys could be increased greatly by a certain kind of heat-treatment, but the discovery has been used to so much advantage that a wide range of alloys has been placed at the disposal of engineers, combining the lightness of aluminium with mechanical properties comparable to those of mild steel. Heat-treatment was applied first to wrought alloys only; its application to cast material dates back only a few years, but is now becoming comparatively common, though not nearly common enough to justify the author's statement that "a relatively small bulk of the ordinary commercial castings are used unheat-treated. . . ."

The book is clearly written, and does just what the title suggests. It describes the theory of heat-treatment of aluminium and its alloys, and explains clearly the advantages of the various processes, as applied both to cast and wrought material. The author has aimed at making the book useful to practical metallurgists, and therefore gives details of the heat-treatment conditions (time, temperature, etc.) most suitable for the numerous commercial alloys, and describes the types of equipment that have proved satisfactory in practice. A commendable feature of this section of the book

is that the information is really up-to-date. The theoretical part of the subject is adequately treated, and is illustrated with numerous excellent photomicrographs, which, however, lose some of their value through being too briefly described.

The book can be confidently recommended to all those interested in light alloys.

M. S. Fisher.

Protective Films on Metals. By Ernest S. Hedges, D.Sc. [Pp. xi + 276, with 23 text-figures.] (London: Chapman & Hall, 1932. Price 15s. net.)

This book is the fifth volume of a series of monographs on applied chemistry, and the author throughout has kept the book on the practical basis implied by this description. There can be few subjects in which a monograph of this description is more desirable, both on account of the great variety of purposes for which some knowledge of the methods by which a metal may be protected from corrosion is desirable, and also because it must be rare for the relevant material to be so scattered throughout the literature of the scientific journals and the patent specifications of the world.

An introductory chapter gives a summary of the present views on the mechanism of corrosion, and immediately introduces the idea which is ascribed to Faraday, that a metal such as iron is protected from further corrosion by a skin of its oxide. Incidentally, as Prof. Rideal recently pointed out, this idea was first put forward by Boyle, and such a skin was actually isolated by him. The principal thesis of the chapter is that there are very many ways in which corrosion may be induced, not the least of them being the incomplete application of a protective film.

A more detailed description is then given of the protective effects of oxygen in covering the metal with a film of oxide, together with that of the isolation and the properties of this film. Some account is given of the tarnishing of most of the common metals, but in some cases at least this seems rather incomplete; for example, while the author quotes the rather curious observations of Feitknecht, that the "parabolic law" breaks down for copper wires, the explanations given by Wilkins and others is not mentioned. The impression is given that in many cases the rate of oxidation is controlled by more than the rate of diffusion of oxygen through the oxide film, but it seems to the reviewer that the evidence for this depends more on the failure to find an expression determining the rate of diffusion of the gas through such a complex system as the irregular oxide layer, than on any experimental fact.

The two chapters devoted to corrosion in liquid systems contain, amongst other things, an interesting discussion of the passive state of iron and other metals in which the great mass of material has been particularly well brought together. The same applies to the section of anodic passivity, in which Müller's theory and the steps by which the passivity of metals has been identified with the formation of a protective film are traced.

The first two-thirds of the book are of a primarily general and theoretical nature, but the end of the book is predominatingly practical. Here may be found descriptions of the methods adopted for protecting metals by the various technical processes of hot-dipping, electroplating, cementation, or giving the metal an artificial covering of another metal, point, lacquer, enamel, etc. There are a good many practical details given here which are likely to be of great service to many people, and the reviewer noticed a number of points which might usefully be known to every worker in a laboratory. It is very clearly and compactly written.

So far no mention has been made of the many cases of periodic chemical change which are included among the many corrosion phenomena. It was

not to be expected that Dr. Hedges, who has done so much of this interesting work himself, would omit some account of the relevant points, and the reviewer read these passages with particular pleasure.

O. H. W.-J.

The Donnan Equilibria, and their Application to Chemical, Physiological, and Technical Processes. By T. R. BOLAM, M.Sc., D.Sc. [Pp. vi + 154, with 12 figures.] (London: G. Bell & Sons, 1932. Price 9s. net.)

BEFORE examining this book, the reviewer doubted the possibility of writing a coherent and useful book covering the many applications of the Donnan Equilibrium Theory, that is to say, of including all the manifold cases in which an effect due to the separation of electrolytes by a membrane that is not permeable to all the ions present, is to be considered. Dr. Bolam's book resolves these doubts, and the book is certainly interesting and useful, but the author prefers to make the book a connected account of a great many of the cases involved, rather than a comprehensive summary of all the possible applications. Of the wisdom of his choice there can be no doubt.

Of the four chapters, the first is a very good elementary introduction to the theory of the effect. The important point, that the physical existence of a membrane is quite immaterial, provided there is some constraint on the diffusion of the ions, is so stressed that there is no reason why it should be overlooked in the future. The simple chemical applications which served to establish the validity of the thermodynamical treatment are discussed at length in the second chapter, and from the point of view of the student this is the most useful part of the book, since the concrete instances are much easier to grasp than the ideas of the theory.

The last two chapters deal with the practical applications, and it is here that a selection from the numerous possible cases has been made. Amongst the subjects treated are the electrolyte distribution in the blood between cells and serum, and in other body fluids, an interesting account of the swelling of gels, including cotton fibres and leather, and certain purely physico-chemical applications, such as the "ultra-centrifuge," the viscosity of protein solutions, and electrokinetic potentials and cataphoretic velocity are discussed. The few pages devoted to each of these subjects are always sufficiently to the point to justify their inclusion, and sufficiently complete to be valuable.

This must have been a very difficult book to write and the author must be congratulated on his success in making it so interesting. Messrs. Bell have done their share in making it attractive.

O. H. W.-J.

Potentiometric Titrations. A Theoretical and Practical Treatise. By I. M. KOLTHOFF and N. HOWELL FURMAN, Ph.D. Second Edition. [Pp. xiv + 482, with 74 text-figures.] (New York: John Wiley & Sons. London: Chapman & Hall, 1931. Price 36s. net.)

SINCE potentiometric titrations form the most important of the electrometric titrations, and since Prof. Kolthoff has probably done more than anyone to make this so, any book on this subject with his name on the back is assured of a welcome. This is a second edition of his book that was first published in 1926, and contains all that is new since that time. To prevent the book from becoming too unwieldy, the authors have omitted the original first three chapters, which contained a general introduction to the principles of Volumetric Analysis, in favour of an introductory chapter on Electrode Titrations and Potentiometric Titrations. This change will probably be generally thought to be desirable, especially since this new chapter is a particularly good one, brief though it is. The next three chapters are all more or less theoretical, and are also elementary: the authors obviously

regretted that they did not feel justified in discussing the activity coefficients of the ions, and this regret is shared by the reviewer. In two short passages only is it mentioned that the concentrations of the ions are not the determining factors, but rather the activities. On p. 3 it is stated that " this difference is not usually very significant in potentiometric titrations," and later (p. 201) of the difference between the true hydrogen-ion activity and the pH as usually calculated " the question is not of practical importance." Certainly no great error can ever be introduced in this way, and if this book is primarily intended as a practical manual, this omission is not only desirable but necessary, but since to the reviewer, at all events, the book is so much more than this, he wishes that a little more space had been devoted to this question and some discussion given of the order of magnitude of the error likely to be introduced.

Certainly as a practical manual on the subject it would be next to impossible to excel this book. Part 2 of the book, containing over seventy pages, is devoted to a general discussion of the technique of potentiometric titrations, and the reviewer has found in practice that the descriptions of the methods that are given are sufficiently clear and detailed as to render any search of the original papers redundant. Part 3, entitled " Practical Applications," makes up the greatest part of the book, and includes a detailed discussion of all the better-known potentiometric titrations, with references to, and short descriptions of, a host of more obscure ones. So numerous are these latter that one cannot help believing that a great number of routine works analyses, now carried out with indicators, could be better carried out by the methods described here. It may well be that this new edition will serve further to widen the use of this very convenient technique.

The book is concluded by some forty pages of bibliography, some useful tables, and a really excellent index, which seemed on trial to be complete without being cumbrous, and to involve a minimum of time in finding the particular titration required. It is clear that this book is required in all research laboratories and in all laboratories where inorganic estimations are carried out in any number. It is very well produced, as, it must be admitted, its price demands.

O. H. W.-J.

GEOLOGY.

Geology of Petroleum. By W. H. EMMONS. Second Edition. [Pp. xi + 736, with 435 figures.] (London: McGraw-Hill Publishing Co., Ltd., 1931. Price 30*s*. net.)

THE first edition of this work was published in 1921, but oil-field developments and the study of oil geology move so rapidly that this second edition is, to all intents and purposes, a new book. All the chapters have been re-written, half the former illustrations have been discarded and have been replaced by some 350 maps, cross-sections, and other figures. The book is primarily intended to serve as a textbook of the geology of petroleum, natural gas, and related materials, and secondarily as a compendium or manual relating to the geology and deposits of specific oil-bearing areas. It fulfils both these objects excellently and with close regard to the needs of students.

The first half of the book is occupied by general matter dealing with the surface indications, properties, and origin of petroleum; the openings in rocks, and the characters of reservoir and cap rocks; the modes of accumulation of petroleum, and the structural features of oil and gas reservoirs. The mapping of oil strata and logging of wells; the behaviour of wells and relation to rock pressure; and the deformation of petroliferous strata in relation to carbon ratios of associated coals, form the subjects of further chapters.

The remainder of the book deals with the geology of the oil-fields of the world. Naturally, North America, which provides 75 per cent. of the world's oil,

occupies seven chapters out of twelve devoted to this subject; but an attempt has been made to deal with geologically interesting and instructive oil-fields in disregard of their commercial importance. All the accounts are clear, concise, and extremely well illustrated by maps, sections, and diagrams.

In his preface the author provides a serious warning concerning the future of the world's oil-supply, and especially the situation in the United States. Many of the greatest fields in the latter country are now draining oil from the deepest possible reservoirs, and no geological work however skilful, and no improvement in drilling and recovery technique however revolutionary, will make it possible to obtain oil below many of the horizons that are now being exploited. The conclusion is that a very serious shortage of oil will occur in a few decades, especially in North America, where development and exhaustion are far more advanced than in other continents. Measures should be taken at once for conservation and rationing of oil-supplies.

This very comprehensive and useful textbook is provided with a good index, and is well printed and produced. While the illustrations are excellent, the type used on a few of the maps is so small as to be difficult to read.

G. W. T.

Elements of Optical Mineralogy. An Introduction to Microscopic Petrography. Part I. Principles and Methods. Fourth Edition, Revised and Enlarged. By A. N. Winchell. [Pp. xii + 248, with 270 illustrations.] (New York: J. Wiley & Sons; London: Chapman & Hall, 1931. Price 21*s*. net.)

The third edition of this standard work was reviewed in Science Progress, October 1929, p. 354. The lapse of only three years before a fourth edition was called for is a tribute to the value of Prof. Winchell's textbook. The most important advance in the mineralogical field covered by this book during the interval has been the continued improvement of methods for measuring indices of refraction by immersion liquids. This improvement involves not only modifications of apparatus and technique in the use of the double variation method of measuring refractive indices, but also a modification of the Federof universal stage which makes for greater simplicity in its manipulation. Consequently, this edition includes considerable changes and additions in the final chapter which deals with the universal stage, but only minor changes and corrections in the main body of the work. Prof. R. C. Emmons, who has been mainly responsible for the improvements in apparatus and technique, has contributed a valuable section on the use of graphic methods for the improved universal stage, in illustration of which four excellent plates are enclosed in a pocket on the back cover. This work well holds its own as the best available textbook for the advanced student of optical mineralogy.

G. W. T.

A Manual of Determinative Mineralogy. With Tables for the Determination of Minerals. By J. V. Lewis. Fourth Edition, revised by A. C. Hawkins. [Pp. ix + 230, with 76 figures.] (New York: J. Wiley & Sons; London: Chapman & Hall, 1931. Price 18*s*. net.)

The fourth edition of this well-known manual has been prepared by Prof. A. C. Hawkins, of Rutgers University. The book is divided into two main sections dealing respectively with physical properties of determinative value, and determination by blowpipe tests. Tables on the above two bases occupy most of the book. The principal basis of classification in the physical tables is the nature of the streak. Very careful descriptions of the various blowpipe and chemical tests of minerals are given, and the special difficulties of students new to the subject are kept well in view. The blowpipe tables are based first on the possession or not of metallic lustre, secondly, on the fusibility, the

other tests following in proper order. The minerals are finally tabulated according to their crystal system, lustre, and hardness, with cross-references to the physical and blowpipe tables. The book closes with a good glossary and full index. It strikes the reviewer as one of the most useful manuals of determinative mineralogy that he has seen.

G. W. T.

Determination of the Opaque Minerals. By C. M. FARNHAM. [Pp. vii + 236.] (London: McGraw-Hill Publishing Co., Ltd., 1931. Price 17*s.* 6*d.* net.)

THE microscopy of minerals which are transparent in thin section has reached a very high stage of development. It is now the turn of the opaque minerals which are not amenable to many of the modes of determination used for transparent varieties. The methods used for opaque minerals have been developed mainly in the United States under Graton and his collaborators (Harvard), and in Germany under Schneiderhöhn (Freiburg), and Ramdohr (Aachen), whence most of the manuals and textbooks dealing with the subject have emanated.

Farnham's book follows the plan of its predecessor by Davy and Farnham, but presents a much fuller treatment. The opaque ore minerals are polished, and examined by the metallurgical microscope, whereby their optical properties under vertical illumination by reflected light are determined. Certain physical and micro-chemical characters are also utilised in their identification. The book begins with a section on technique of preparation and examination of samples, followed by 110 pages of short descriptions of over 200 opaque minerals. The main determinative tables which follow occupy 32 pages, and are based on etch reactions with various chemicals. The book concludes with numerous supplementary tables, in which the minerals are arranged in accordance with various physico-chemical tests.

The book is addressed to students of ore deposits, economic geologists, mining and metallurgical engineers, who are presumed to have access only to simple types of apparatus. Hence the more difficult methods involving the use of complicated and expensive apparatus are given only passing mention.

The work is likely to be of value to the clientele it is designed to serve. Unfortunately, however, it is marred by many mis-spellings, minor errors of detail, and inexact references.

G. W. T.

Dalradian Geology. The Dalradian Rocks of Scotland and their Equivalents in Other Countries. By (the late) PROF. J. W. GREGORY, D.Sc., F.R.S., LL.D. [Pp. xi + 188, with 4 plates, 16 diagrams, and 2 maps.] (London: Methuen & Co., 1931. Price 12*s.* 6*d.* net.)

THIS work has a melancholy interest, as it is the last book published by Prof. J. W. Gregory before he embarked on that expedition to Peru on which he met his death in the dangerous rapids of the River Urubamba. The intricate and difficult geological problems of the Scottish Highlands held a great fascination for him, and for the whole period of his twenty-five years' occupancy of the Chair of Geology at the University of Glasgow he spent every available week-end among his beloved mountains. The present work brings together the stratigraphical and structural details thus accumulated, summarises the salient results, and compares the Dalradian rocks of Scotland with their presumed equivalents abroad. Chapter 1 introduces the Dalradian problem, and Chapter 2 deals with the classification of Pre-Cambrian rocks in general, and the equivalents of the Dalradian System in other regions. Chapters 3 to 7 give the details of field traverses over the various Highland regions and formations. Chapter 8 gathers up the threads of classification, and gives the author's tabular summary of Dalradian successions in nine

different areas. Chapter 9 and last elucidates the general structure of the Southern or Grampian Highlands.

The Grampian Highlands, representing the worn-down remnants of a folded mountain chain of Pre-Cambrian age, is naturally of great structural complexity, so great it is hardly surprising that almost every worker in this field has formulated a different theory of its succession and tectonics. Prof. Gregory's views are expressed in his own characteristically lucid manner, and have the advantage of relative simplicity compared with the views of other workers; but it is possible to doubt whether the simplicity of his theory of structure is matched by the rocks themselves. We may perhaps also question the value of long-range inter-continental correlations of Pre-Cambrian formations, when correlation is so uncertain within the limits of a small country like Scotland. Prof. Gregory will have none of the more extreme theories of the Alpine "nappist" school, holding that the Dalradian rocks exhibit a much deeper tectonic level through erosion, and show flow and recrystallisation structures appropriate to the deeper zones, rather than the overthrusting and mylonitisation characteristic of the lightly loaded and more brittle higher levels of Alpine type. He institutes a new formation—the Lennoxian—by separating from the Dalradian the relatively unaltered grits, greywackes, and slates of the Southern Highland border.

The plates are microphotographs of thin rock slices, and cannot be said to possess much value. The map, however, which has been drawn by Dr. W. J. McCallien from Prof. Gregory's sketches, is an excellent production. Subject, author, and locality indexes, together with a full bibliography, are provided.

G. W. T.

Coral Reefs and Atolls. By J. STANLEY GARDINER, F.R.S. [Pp. xiii + 181, with 15 plates and 33 figures.] (London: Macmillan & Co., Ltd., 1931. Price 10*s*. 6*d*. net.)

THIS study of coral reefs and atolls represents the conclusions of thirty-five years of work on the subject, and is based on a course of eight lectures given to the Lowell Institute of Boston in 1930. The composition, structure, and origin of coral reefs and atolls is one of the borderland subjects of science, to which biologists, geographers, and geologists may be expected to contribute relevant material. Mr. Gardiner approaches the problem mainly from the biological side, but he has also excellent qualifications upon the geological and geographical sides.

The introductory chapter describes the general characters of fringing, barrier, and atoll reefs, and the second the characters of island formations. Then come successive chapters on the natural history of corals, other plant and animal reef builders, and other organisms found on reefs. The sixth chapter deals with geographical distribution of reef formations, the seventh with atolls and their lagoons, and the eighth and final chapter with the crucial problem of the foundations of atolls. An appendix describes the islands and coral reefs of the Pacific Ocean.

The statements concerning the importance of the geological work of sand feeders, such as holothurians and worms (pp. 101–3), come rather as a surprise. Rock-boring organisms and algæ are also agents of destruction on the reefs. Darwin's "beautiful and attractive" theory of subsidence for the origin of atolls is killed, in the writer's opinion, by the ugly fact that there is no such general filling-in of lagoons by coral growth and by sediments as is demanded by the theory. Mr. Gardiner does not agree with Prof. W. M. Davis's attempts to substantiate Darwin's theory by consideration of the physiographical evolution of coral islands and coasts; but he looks with a kindlier eye on theories such as Wharton's and Daly's which dispense with subsidence, and rely on proposed methods of formation of broad submarine platforms at less

than 50 m. depth on which reef organisms can flourish. The author suggests, in conclusion, that all present coral-reef theories fail for lack of sufficient data. "We know to-day the broad general building potentialities of our organisms, and it is for the geophysicist to give us the foundations upon which they have built." The book is illustrated by excellent plates and maps, and is provided with a good index.

G. W. T.

German-English Geological Terminology. An Introduction to German and English Terms used in Geology, including Mineralogy, Petrology, Mineral Deposits, etc. By Dr. W. R. Jones and Dr. A. Cissarz. [Pp. xvii + 250.] (London: T. Murby & Co.; Leipzig: Max Weg, 1931. Price 12*s*. 6*d*. net.)

This valuable work is cast into the form of an elementary textbook in which the English and German texts are placed side by side, paragraph corresponding to paragraph, and with the important words italicised on either side. This method brings out almost amusingly the more profuse verbiage of the German language, the paragraphs almost invariably being longer on the German side than the English. The book will be of most use to geological students who are making their first acquaintance with German (or English) texts; but, notwithstanding the authors' expressed hopes, we do not think that it will appeal to senior geologists, to whom an English-German dictionary of geological terms would certainly have been more acceptable. We make the suggestion that an extension of this work in the form of a dictionary or glossary, including the multifarious terms used in recent German works on geology and cognate sciences, would be worth doing—a dictionary in which perhaps the German co-author might explain the usages of the term *Beanspruchung* and of the corresponding verb in recent German books. Many notable omissions from the present book might be included therein, as, for example, among the Z's, *Zerreibung*, *Zerbrechung*, *zerfallen*, *Zertrümmerung*, *Zusammenschub*, *zitzenformig*, etc. We think also that the space devoted to appendices giving the English-German of the chemical elements and of minerals, 90 per cent. of which are indicated by the same word in each language, is wasted. Nevertheless, this work forms an excellent introduction to German for geological students which we can heartily recommend.

G. W. T.

Sands, Clays, and Minerals. A British Magazine devoted to Economic Minerals. Vol. I, No. 1, April 1932, 40 pp.; No. 2, September 1932, 60 pp. (Chatteris: A. L. Curtis. Price 5*s*. per annum.)

The two first numbers of a new magazine entitled *Sands, Clays, and Minerals*, have come to hand. This periodical is devoted to the study of economic minerals, and is published quarterly by A. L. Curtis, of the Westmoor Laboratory, Chatteris. The first number contains some instructive articles on Black Diamonds, Sands in British Industry, Slate, Portland Cement, Lithographic Abrasives, Analysis of Clay; and in the second number there are valuable papers on Osmiridium in Tasmania, Australian Opals, Ontario as a Metal Producer, Fuller's Earth, Rock Sections, Little-known Uses of Clay, and the Modern Roadstone Quarry—a list which indicates very well the wide range of interests covered by this journal. The illustrations are excellent, especially some coloured reproductions of gemstones, but we may perhaps be permitted to query the use of publishing expensive plates illustrating the trade-marks of British cements and fire-bricks. We think that the magazine, although its aims are frankly commercial as well as scientific, caters adequately for a somewhat neglected field in economic mineralogy.

G. W. T.

BOTANY.

Recent Advances in Botany. By E. C. Barton-Wright. [Pp. viii + 287, with 60 illustrations.] (London: J. & A. Churchill, 1932. Price 12*s*. 6*d*. net.)

This work is a companion volume to the author's *Recent Advances in Plant Physiology*. The subject-matter is divided into nine chapters, each treating of an aspect of Botany in which research has been active in recent years. The first treats of theories of plant structure, such as the phyllodic nature of the Monocotyledonous leaf and cotyledon, carpel polymorphism, and the relation of size to form. These constitute summaries of the well-known views of Bower, Arber, and Saunders. Other aspects of morphological and anatomical advance are entirely omitted. In the second chapter on Palæobotany the very important work of recent years on Post-glacial floras is omitted. The third chapter, on "The Species Concept," deals mainly with the work of Turesson. The next three chapters are devoted to the fungi of which the first deals mainly with the Mycetoza and the phenomenon of brachymeiosis and the last two with heterothallism and mycorrhizal relations. Two more chapters are devoted to the Phæophyceæ and Florideæ, whilst the final chapter treats of virus diseases.

As a summary of certain aspects of recent work in the field of botany, students will doubtless find some of these chapters useful, but as a presentation of recent advances in the subject, as a whole, on the non-physiological side, it leaves something to be desired as regards presentation, and there are other important omissions besides those already alluded to, especially in the domains of ecology, taxonomy, and geographical distribution.

E. J. S.

Principles of Soil Microbiology. By Prof. S. A. Waksman. Second Edition. [Pp. xxviii + 894.] (London: Ballière, Tindall & Cox, 1931. Price 52*s*. net.)

When the first edition of this book appeared in 1927 it was at once apparent that we had here a standard work which constituted a valuable conspectus of existing knowledge, and therefore the fact that a new edition has so soon been called for is not merely a tribute to its proved usefulness, but an indication of the rapid progress in this field. So active has been research on the microbiology of the soil during the past four years, particularly in respect to the decomposition processes which organic matter undergoes, that a complete revision of the text has been necessitated and sections have been completely rewritten. By the omission of some of the less important matter of the previous edition the present work has been revised with no appreciable addition to its bulk.

How large is the field covered can be realised when we pause to consider the wide range of groups represented in the soil from the diverse soil algæ and autotrophic bacteria to the numerous organisms, heterotrophic bacteria, actinomyces, soil fungi, protozoa and flagellates which are dependent upon the organic material present. Within each of these large groups there are numerous representatives with the most diverse chemical activities, and any adequate knowledge of the biology of the soil involves both a detailed acquaintance with the individual requirements of each, and also of the interaction of their activities with one another. It is largely due to the author's own investigations that we know how important a rôle is played by the actinomyces, so largely responsible for the cellulose decomposition in the soil. So, too, the recognition of a definite algal flora in the soil is of comparatively recent date, as also is much of what we know respecting soil fungi and protozoa. This knowledge is widely scattered in specialist journals, so that a résumé of

our knowledge such as Prof. Waksman supplies, with numerous bibliographical references, is of the greatest value to student and investigator alike.

A real ecology of the soil is yet to be attained, but the analytical treatment, though admittedly an abstraction, is a necessary preliminary to that understanding of the synthetic relationships at which we aim, and a work such as that before us is an important step in this direction. In this connection the chapter on the relationships between higher plants and micro-organisms serves to emphasise the complexity of the problems involved and to point the direction of future progress.

E. J. SALISBURY.

The Coconut. By EDWIN BINGHAM COPELAND, Professor of Plant Physiology and Dean of the College of Agriculture (retired), University of the Philippines. Third edition. [Pp. xxvii + 228, with 27 illustrations and frontispiece.] (London: Macmillan & Co., 1931. Price 20s.)

THIS edition follows closely the second edition published in 1921, with the addition of material to bring the work up-to-date; this is especially noticeable under the headings of diseases and pests. In 1921 the crop was a very profitable one indeed, and even now with world-wide depression it compares more than favourably with other large tropical crops such as rubber and sugar. It remains to be seen whether new uses can be found for its products to lead to such an expansion of the industry as was caused by the advance in oil technology.

Prof. Copeland began his study of this plant twenty-seven years ago, and the work provides an authoritative account of its culture and principal uses for all those who are interested.

E. M. C.

ZOOLOGY.

Bees, Wasps, Ants, and Allied Insects of the British Isles. By EDWARD STEP, F.L.S. [Pp. xxv + 238, with 44 plates in colour showing 470 figures, 67 plates showing 170 photographic reproductions and text illustrations, also 64 wing maps.] (London and New York: Frederick Warne & Co., Ltd., 1932. Price 10s. 6d. net.)

THE publishers of "The Wayside and Woodland Series" are to be congratulated on adding this volume to their series of such handy and useful books for the rambler, field naturalist, and others. Mr. Step has done much to popularise natural history, and in this series alone has been responsible for volumes entitled *Wayside and Woodland Blossoms*, *Wayside and Woodland Trees*, *Wayside and Woodland Ferns*, and *Animal Life of the British Isles*. In the volume under review the author gives an admirable account of the insects classified as Hymenoptera. It is deeply to be regretted that he did not live to see it published.

A glance at the subject headings reveals the scope of the book: Wing maps (a novel yet good feature), Humble Bees, Cuckoo Bees, Social Wasps, Potter Wasp and Mason Wasp, Velvet-ants, Spider-hunting Wasps, Sand Wasps, Black Wasps, Digger Wasps, Wood-boring Wasps, Solitary Bees, Mining Bees, Carpenter Bees, Homeless Bees, Ants, Ichneumons, Chalcis-flies, Sawflies, Gall-flies. To complete the book there is a list of useful books for reference, a classified index to genera, a glossary of terms, which should be very useful, and a general index.

One of the outstanding points of the book is the illustration. The coloured pictures are well up to the high standard set by previous volumes, for example, South's *Moths of the British Isles*. Naturally, it is not possible to identify all the insects by the illustrations given, but in almost every case one would get a very fair idea of the correct placing of the latest capture or observation.

The photographs are an exceptionally good collection, chosen from those of the best natural history photographers.

The style of the book and its contents can but thrill the schoolboy, and indeed his parents, opening up as it does new fields hitherto approached only by learned treatises. The information given is accurate and the author has not failed to make use of the latest research. We consider that the use of the term gall-flies for the Cynipoidea is a pity in view of the fact that this term should be retained for some of the true flies or Diptera, and there is already an adequate term, *viz.* gall-wasps.

It has always seemed curious that so much attention has been given, by publishers of popular books on natural history, to butterflies and moths; thereby causing the average man to remain satisfied in calling a wasp a wasp, a bee a bee, and a fly a fly, and not always even correctly at that. We venture to hope this book will have the success it deserves and sufficient to entice the publishers to produce a similar book on British Flies.

H. F. B.

Hearing in Man and Animals. By R. T. BEATTY, M.A., B.E., D.Sc. [Pp. xi + 227, with 99 illustrations.] (London: G. Bell & Sons, Ltd., 1932. Price 12*s.* net.)

BOOKS on scientific subjects written with the dual purpose of serving the needs of the general reader and the expert are not usually a success. Dr. Beatty has, however, done it uncommonly well, in this comparative survey of the sense of hearing. He is clearly alive to the necessity of searching widely for his facts. Few biologists or physicists realise the wealth of first-class observations bearing on this and allied subjects, hidden away in contemporary psychological journals.

The book is a mine of information on everyday problems. City councillors might profitably study the chapter on Noise (p. 183), and would-be musicians might be tried out for their frequency discrimination as described on p. 74, both to the advantage of society. Considerable space is devoted to a discussion of current theories of audition, and there are informative chapters on Music, Sensations of Hearing (Normal and Pathological), and a somewhat speculative chapter on the Evolution of the Ear. The survey of hearing in animals is a useful summary of some of the known data.

There are several references to the otoliths of fishes. Bony fishes differ considerably from cartilaginous fishes in their otolith arrangements. This might have been more clearly stated, as it has some bearing on his theoretical discussion of the evolution of the ear. The reference to the behaviour of the cod (p. 136) is out of place, as it refers to an experiment on temperature, not auditory discrimination. The most important work on pitch discrimination in the dog (p. 143), although carried out in Pavlov's laboratory, was done by G. V. Anrep, to whom also should be accorded some recognition for his translation and editing of Pavlov's book—*Conditioned Reflexes.*

Dr. Beatty's book fills a decided gap and should find an appreciative public, for it is attractively written, well printed, and reasonable in price.

H. O. BULL.

A Textbook of Practical Entomology. By FRANK BALFOUR-BROWNE, M.A. (Oxon. et Cantab.), F.R.S.E., etc. [Pp. viii + 191, with 116 figures.] (London: Edward Arnold & Co., 1932. Price 18*s.* net.)

THE teacher of entomology has been compelled in the past to create very largely his courses in practical work, based upon his own experience and from existing general textbooks. As entomology is a comparatively new subject for teaching, this absence of any standard book on the practical side has been inevitable and has had its natural advantages. It has made the young

lecturer think out for himself trial courses. But now that the first experiments in the type of courses required have been made and the subject is being taught more generally, it is as well to have a standard set. Some teachers, notably Needham (*Elementary Lessons on Insects*, 1928) and Handschin (*Praktische Einführung in die Morphologie der Insekten*, 1928) have already given us examples of practical courses.

Prof. Balfour-Browne, whose teaching experience at Cambridge and London well qualifies him for the task, has now done the same for English teaching institutions. Other instructors doubtless will adapt the book to suit their own views and requirements, but all will agree that it is a sound basis for such courses.

The book is divided into three parts, taken largely from actual lecture notes, representing three courses. The first is an elementary one, the second an advanced one, and the third is entitled "The Principles of Systematic Entomology." This last course might be called "Systematic Entomology without Tears," but in reality is a Special Morphology course, as the author mentions in his introduction. It is intended for students taking up entomology as a profession. We do not like the title of this course in these days when *The Principles of Systematic Entomology*, by G. F. Ferris, should have been read and its lessons taught. Systematic entomology includes far more than the mere morphological characters of insects.

Each part consists of notes on the course and ends with a syllabus of a course based upon them. The elementary course is suitable for 20 hours' practical work, the advanced for 48 hours, while the third requires 60 hours. Each course starts with an insect (the cockroach, *Dysticus*, and the grasshopper respectively), which is taken to illustrate external characters and to serve as a model for dissection.

The illustrations, while good and numerous, are of a diagrammatic type, which will compel the student to draw what he sees or else acknowledge his skill in the lazy art of copying. The make-up of the book is pleasingly unostentatious, although the price is rather high. Prof. Balfour-Browne has accomplished his work well. But surely space could have been found to mention the value of practical field work accompanied by a competent field entomologist and a scheme of such work for the different seasons.

H. F. B.

An Illustrated Synopsis of the Principal Larval Forms of the Order of Coleoptera. By ADAM G. BÖVING, Ph.D., and F. C. CRAIGHEAD, Ph.D. [Pp. 351, with 125 plates.] (Brooklyn, New York: Brooklyn Entomological Society. Reprinted from Vol. II of *Entomologica Americana*, 1931. Price $6.50. Bound cloth, $7.50.)

REALISING how the extensive gaps in the comparative knowledge of the external morphology of Coleopterous larvæ have severely handicapped descriptive work, the authors, as they state in their introductory note, had already projected in 1915—what must have been the dream of many workers—a survey of the whole order. The collections of the Bureau of Entomology, and of the U.S. National Museum which possesses many European species, provided the material. The results of this research appeared as a serial in *Entomologica Americana* for November and December 1931, and is here collected in one cover.

The book consists of two main parts, one a dichotomous key designed to separate larvæ into their families or sub-families along phylogenetic lines and amplified by useful footnotes; the other, and this is the major part of the book, a series of 124 clear and excellently reproduced plates figuring about 500 larvæ or larval characters of taxonomic significance. These represent some 145 families, of which those that are better known, *e.g.* among the Adephaga, Cerambycoidea, Scarabæiodea, are intentionally less well represented than

the lesser known. Finally, plate 125 indicates graphically the author's ideas as to phylogenetic relationships of the different families.

For, as we are told in the preface, the keys are meant not only for identification purposes but also as a contribution to the discussion of the natural grouping of the Coleoptera. To this end the three-page introduction indicates briefly the relationships between the different series, while further remarks on family associations within the series are to be found in their appropriate places in the keys.

Apart, therefore, from the general worker, to whom the book will be indispensable, specialists will be particularly interested to see the nature of the light that is shed on the rival systems of classification. It would be out of place to discuss this here, but the authors state the classification arrived at agrees fairly well with that of the imagines, more particularly that of Leng. Nevertheless, there are considerable rearrangements in many of the series, and 153 families are recognised in the Conspectus. The authors also confirm the necessity of recognising, as some workers have realised from study of the imagines, a new sub-order, the Archostemata of Kolbe, to contain the primitive families Micromalthidæ and Cupesidæ.

This book will be warmly welcomed by all students of the Coleoptera.

H. C. F. N.

Outline of Comparative Embryology. By Aute Richards. [Pp. xvi + 444.] (New York: John Wiley & Sons; London: Chapman & Hall, 1931. Price 30*s*. net.)

The author, who is Professor of Zoology at the University of Oklahoma, rightly considers that a broad general knowledge of the principles of comparative embryology is indispensable as a basis for more specialised study. Finding nothing that quite covers the ground in English, he has prepared the present useful volume as a textbook for a general course in comparative embryology. He does not attempt to deal with experimental embryology, save incidentally where it throws light upon morphological problems. He holds that experimental embryology "runs the danger of considering only processes and those out of relation to structures. It is in structures that functions are inherent, for one cannot understand the workings of a machine with which he is unfamiliar. Morphology in its descriptive phases is therefore basic to a proper attempt to work out functional relations. Our admiration for the attempts to secure an intelligent conception of the mystery which underlies the pageant of development must not allow us to disregard the importance of a foundation of knowledge of descriptive embryology" (p. xiv).

In Part I the main facts of descriptive embryology are set out; the treatment is comparative, not by systematic groups. "It is sought to show how the single-celled fertilised egg arrives at the multicellular condition characteristic of the fully formed, but undifferentiated, young organism in which the organ systems are established." It seems to us that rather too much attention is paid to the details of cleavage and of cell-differentiation generally. The relation between cell-division and differentiation, in the early stages at least, is not necessarily a close one. An interesting section in Part I deals with the various types of invertebrate larvæ and their relations to one another.

In Part II some general problems of embryology are considered, for example the origin of germ-cells, the recapitulation theory, asexual reproduction, parthenogenesis, and, in outline, the problem of the "determination" of characters in the ovum.

The book is illustrated by 224 figures, and contains a useful glossary and some twenty pages of bibliography.

E. S. Russell.

Early Man, his Origin, Development, and Culture. By G. Elliot-Smith, Sir Arthur Keith, F. G. Parsons, M. C. Burkitt, Harold J. E. Peake, and J. L. Myres. [Pp. 176, with 32 text-figures and 12 plates.] (London: Ernest Benn, 1931. Price 8s. 6d. net.)

This little book consists of six lectures, each by a famous authority on his subject, delivered before the Royal Anthropological Institute. Each subject is thus dealt with in essay form and constitutes a complete section of the book, independent of the others. Since the book is not intended as a textbook, but rather as a popular exposition of some of the more interesting aspects of anthropology, the lack of cohesion, inevitable in a symposium, does not seriously detract from its value and is more than compensated for by its versatility.

Prof. Elliot-Smith deals with the evolution of man from his pre-human ancestors in a very fascinating essay. Having outlined our knowledge derived from the chief fossil remains of early man and of Pithecanthropus, Eoanthropus, of the recently discovered Peking Man, Sinanthropus, etc., he goes on to discuss the part which vision has played in the evolution of the human brain. The book is well worth buying for the sake of this essay alone.

The Evolution of Human Races is dealt with by Sir Arthur Keith. Having pointed out the continuous trouble in our world resulting from the differentiation of mankind into races, he goes on to outline the racial types of to-day. Some of the factors concerned in race building are then discussed, and it is shown that patriotism is an essential one. It is claimed that "a nation always represents an attempt to become a race; nation and race are but different degrees of the same evolutionary process." This leads to an analysis of the behaviour of young nationalities, in which Finland, the Irish Free State, and the Nationalist Movements in Wales and Scotland are considered amongst others.

Prof. Parsons's lecture deals with the racial types which have gone to the Making of the Modern Englishman and the traces of these which remain in the population to-day.

Mr. Burkitt only summarises his lecture on Most Primitive Art, but it is a fascinating and well-illustrated summary. We wish it could have been longer.

Mr. Peake deals with the beginnings of Agriculture and in particular with the place in which the cultivation of grain began and the manner in which it arose.

Prof. Myres's lecture on Metals is split into two chapters dealing respectively with Precious and Useful Metals, and the part concerned with the early history of gold is particularly interesting.

F. W. R. B.

Dr. L. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz. Band IX, Die Flechten. Abteilung IV. 2, Haefte. Die Gattung Cladonia von Dr. Heinrich Sanstede. Lief. 1 and 2. [Pp. 1–240 and 241–531, with 8 text-figures, 34 plates.] (Leipzig: Akad. Verlagsgesellschaft m.b.H., 1931. Price Mk. 47.50.)

Rabenhorst's *Kryptogamen-Flora*, the separate volumes of which have been appearing at intervals over many years, has always presented standard books of reference. Sanstede's work on Cladonia will add to the reputation of the great Flora. It is the first instalment of vol. IX, and will be welcomed by all lichenologists. For many years Sanstede has made a special study of Cladonia, that most attractive but most difficult genus of lichens. The central countries of Europe have claimed most attention, but references to other lands are not infrequent. Cladoniæ, like other lichens, are symbiotic plants, independent of the substratum, but they are subject to the influence

of their environment of soil, moisture, light, etc., and these varying conditions, as reflected in the species, give rise to bewildering varieties and growth forms, thus increasing the difficulty of identification. Sanstede has paid special attention to these irregularities, but he has been careful to emphasise the specific characters. The Cladoniæ are peculiar in having a primary and a secondary thallus, the primary composed of leaflets (squamules), the secondary of upright stalks termed podetia which, in many species, broaden out at the tip to form a shallow cup or scyphus, on the outer edges of which are borne the fruiting bodies—brown or red apothecia and pycnidia. In the preface is given a full description of the whole plant—the double thallus, its anatomy and development, and also the fruiting structures. The primary thallus frequently disappears, the podetium may grow and branch indefinitely and may persist many years, dying off at the base, but the upper parts continually increasing. A striking example of such long-continued life is provided by *Cladonia rangiferina*, the "reindeer moss" that spreads indefinitely and forms the chief provender of the reindeer, elks, etc., in Arctic regions. Sanstede also notes the presence of certain lichen-acids which can be detected by taste and by the use of alkaline reagents. The main body of the work deals with subgenera and species, of which over seventy are described, with all their numerous varieties and forms, and with special reference to published Exsiccati. Many species and forms are depicted in the plates. The whole work is a most valuable addition to the textbooks of European lichens.

A. LORRAIN SMITH.

Dr. L. Rabenhorst's Kryptogamen-Flora von Deutschland, Österreich und der Schweiz. Band VII, Die Kieselalgen von Dr. FRIEDRICH HUSTEDT. [Part I. Pp. xii + 920, with 1,493 illustrations.] (Leipzig: Akademische Verlagsgesellschaft m.b.H. Price Mk. 63.)

THERE are few more attractive objects for the microscope than diatoms (Kieselalgae), those extremely minute algæ, invisible to the naked eye, that inhabit waters in all countries. They are coated with a fine shell of silica which, at the death of the organism, drops to the bottom of lake or ocean and forms valuable deposits of diatomite. Diatoms take many distinctive forms, but the ornamentation of the shell is the great feature of these algæ—the dots, pores and striations, peculiar and constant to each species, have evoked the admiration of all microscopists. Students of diatoms have been hampered in the past by the lack of available textbooks. The fine scholarly book now before us will be hailed with unusual satisfaction by all who desire to study these minute plants. The first pages are devoted to the history of their discovery and to a description of the organisms—their growth and development. There is also an account of the efforts made by successive workers to formulate a satisfactory classification. They have been finally divided into two great groups—the Centricæ and the Pennatæ; the former being generally salt-water dwellers, while the Pennatæ inhabit fresh waters or moist localities. The Centricæ alone are considered in this first part of vol. VII, and the families, genera and species are treated at length, synoptic keys to genera and species are provided; diagnoses and descriptions are ample. Special praise is due to the generous illustrations of each species, a valuable if not indispensable aid to the student of this group of algæ.

The economic value of diatoms is important: they are the food of crustacea and other minute aquatic creatures: they have been called "the food basis of all sea animals." Diatomite, an extremely fine substance, is used for polishing, etc., and for mixing with nitro-glycerine to form explosives.

A. LORRAIN SMITH.

The Riddle of Migration. By William Rowan. [Pp. xiv + 151, with 11 figs.] (Baltimore: The Williams & Wilkins Company, 1931. London: Baillière, Tindall & Cox. Price 11*s*. 6*d*. net.)

Dr. Rowan, who has himself carried out valuable experimental work at Edmonton in Canada, has succeeded in writing a most readable and fascinating book on a subject of perennial interest—the migration of birds. It can be read with advantage both by the amateur and the professional naturalist. For the benefit of the former an introductory chapter on the general anatomy and physiology of the bird is included.

Why do so many birds that breed in northern latitudes move south before the advent of winter? Many species could not survive a northern winter owing to shortage of food, which is accentuated by the physiological effects of cold. But Rowan points out that this is not the whole story. There is in high latitudes in winter a great shortage of sunlight and particularly of ultra-violet radiation. Lack of this leads to deficiency of vitamin D. "Assuming that vitamin D (like vitamin A) is indispensable to the health of adult animal life, then inhabitants of the north must get their supply either from their diet or from exposure to the sun or from a combination of both. Assuming that their diet is such that they require a certain amount of sunshine per annum, then, to retain their health in years of reduced ultra-violet radiation (*e.g.* persistently cloudy summers), they must (*a*) change their diet, (*b*) move farther south, or (*c*) suffer the consequences. Adoption of the first alternative is extremely unlikely. . . .

"An overwhelming majority of northern birds go south for the winter, and so automatically fulfil the second alternative. The last descends like a guillotine on a small number every decade" (pp. 63–4). By migrating to the south birds seem to avoid the decimating fluctuations which occur in regular cycles in many northern mammals.

Following up this line of thought Rowan has investigated the effect of exposing migratory birds in the autumn to an increased amount of light. This had the extraordinary effect of hastening the development of the gonads; extra exercise had the same effect. As the gonads develop the amount of interstitial tissue diminishes; this is normally at its maximum at the time of the autumn migration. Birds with fully developed gonads, as well as controls with resting gonads, showed no disposition to migrate when liberated in winter. Birds with increasing gonads probably went north. Rowan concludes that diminishing daylight is the main environmental stimulus that arouses the autumnal migratory impulse, and that this acts through a hormone produced by the interstitial tissue.

This is a valuable contribution towards an understanding of the stimuli to migration, but there remain of course many unsolved riddles. The return migration in the spring may be compared to the homing of carrier pigeons, and finding the way back may be a matter of individual topographical memory. The southward migration of young immature birds remains, however, completely mysterious. Probably, as Rowan suggests, we must assume, in addition to natural selection, the Lamarckian factor of the inheritance of acquired habit. The experimental evidence for this is slight, but its possibility has never been disproved, and failing any other reasonable solution we are justified in accepting it provisionally. Rowan works out this view in some detail in relation to known climatic changes in North America since the Ice Ages.

The book, though short, is full of meat, and can be strongly recommended to everyone interested in this fascinating problem.

E. S. Russell.

Biology for Medical Students. By C. C. HENTSCHEL, M.Sc. (Lond.), and W. R. WIRNEY COOK, B.Sc., Ph.D. (Lond.), with a Foreword by G. E. GASK, C.M.G., D.S.O., F.R.C.S. [Pp. x + 618, with 413 illustrations and text-figures.] (London: Longmans, Green & Co., 1932. Price 18*s*. net.)

THE idea of a General Biology is a very good one, and this volume is intended to cover the Biology for the First M.B. Examination of the University of London and similar courses.

The zoological portion of the work is profusely illustrated by well- and clearly-drawn line drawings, and the whole, text as well, is carefully conceived and should prove an excellent introduction to the subject.

The botanical portion, however, is of a very different nature, for a number of serious and in some instances fundamental mistakes have crept into text and figures alike. The moss is represented (in Fig. 200) as having a root and (Fig. 201) a sporangium. On p. 381 the tendrils of the cucumber and the spines of the barberry are given as examples of stipules. In Fig. 228 the stages in the germination of the broad bean would appear to have been drawn from the scarlet runner; Fig. 231 is labelled upside down (plumule should be root, root plumule); Fig. 236 shows pores instead of simple pits, in Fig. 249 the medullary rays of Pinus are not adequately represented; in Fig. 289D the proportions of the dandelion fruit, described as a pappus, are incorrect, and C is the female inflorescence of the hazel and not the nut. In the floral diagram of the Ranunculaceæ the æstivations of the calyx and corolla are shown as spiral, the bluebell diagram has the inner whorl of stamens opposite the carpels, and on p. 437 the diagram of the pea flower has the odd sepal posterior, the sepals opposite the petals, ascending imbrication for the petals and the ovules anterior.

There are many other serious errors, and these are all the more to be regretted as the "get-up" of the book is admirable and the price a very reasonable one.

E. M. C.

Difficulties of the Evolution Theory. By DOUGLAS DEWAR. [Pp. viii + 192, with 7 figures.] (London: Edward Arnold & Co., 1931. Price 12*s*. 6*d*. net.)

THIS book, as its title implies, is devoted to theoretical discussion of facts which, the author contends, are difficult, if not impossible, to reconcile with the evolution theory, even in a modified form. It is suggested that "to account for the phenomena presented by living organisms it would appear to be necessary to adopt a provisional hypothesis of special creation . . . supplemented by a theory of evolution." It is claimed further that such a course would stimulate research. Many biologists, including the reviewer, will find it difficult to accept this suggestion or to believe that if they did it would "stimulate research."

F. W. R. B.

Connecting Laws in Animal Morphology. By HANS PRZIBRAM. [Pp. 62, with 32 figures.] (London: University of London Press, Ltd., 1931. Price 4*s*. 6*d*. net.)

THIS little book consists of four lectures delivered at the University of London dealing with aspects of experimental morphology in animals. The first lecture on Organisation is devoted to the problem of the increase in differentiation and the light thrown upon it by the regeneration of chelæ in Crustacea. The second on Growth deals with the increase in organic mass as exemplified by insects. The third on Symmetry is concerned with growing points as seen in regenerating and transplanted limbs of amphibians. The fourth

and final lecture on modification brings out the relation of metabolic rate to tail length in rats. The whole makes easy and amusing reading, although it may be thought that its substance is somewhat slight.

F. W. R. B.

The Invertebrata. A Manual for the use of Students. By L. A. BORRADAILE and F. A. POTTS, with chapters by L. E. S. EASTHAM and J. T. SAUNDERS. [Pp. xiv + 645, with 458 figures.] (Cambridge: at the University Press, 1932. Price 25s. net.)

THE appearance of a new textbook of the scope of the present work dealing with the Invertebrata is an event of importance in British Zoology. Such a textbook, built on modern lines, has been much needed for many years, and the authors may be sure that the present one will receive a warm welcome. The growth and advance of zoology have rendered the production of a textbook dealing with the whole of the Invertebrata and suitable for final and honours students difficult of achievement within manageable dimensions. Two primary requirements, which are somewhat distinct, have to be met; in the first place, the broad principles of invertebrate morphology, embryology, and comparative anatomy must be clearly presented, free from excessive systematic detail; and in the second place a systematic account of the morphology and embryology of the various groups, illustrated by detailed descriptions of important types, together with some mention of their distribution, occurrence in Britain, habits and mode of life must be given. The ideal textbook would combine both these requisites, but the time is near when such a book would be both too large and expensive for general use by students. The present volume is an attempt to meet both these requirements. The result is commendable in many ways; the descriptions are clear and concise, the illustrations are good, the view-point is modern and invigorating, and the book is produced in a single volume at a moderate price. The exposition of the broad principles of invertebrate morphology is, however, curtailed and its continuity broken by the necessary inclusion of so much systematic detail. On the other hand, the systematic account of the various groups exhibits some remarkable lacunæ. For example, the Gephyrea, including both the Echiuroidea and the Sipunculoidea, are only accorded a page and three-quarters, most of which are taken up with two figures, while the Myzostomata, Acanthocephala, Gastrotricha, and Gordius are not mentioned at all. The chapter on the Protozoa, which is the longest in the book, provides an up-to-date and readable account of this important group, and is, in our opinion, the best in the book. The last chapter deals with the Enteropneusta and Tunicata among the Chordata, which it is thought convenient to include with the Invertebrata. The inclusion of a bibliography, however short, would have been a valuable addition to the book and one which would have rendered it more useful to honours students.

This book, despite any failings, is much too important and valuable to be overlooked, and we hope, and confidently expect, that it will find a conspicuous place on the shelves of every Zoological department's library in the country.

F. W. R. B.

Invertebrate Zoology. By H. J. VAN CLEAVE, Professor of Zoology, University of Illinois. [Pp. xiv + 282 with Frontispiece and 126 figures.] (London: McGraw-Hill Publishing Co., 1931. Price 18s.)

THIS book is intended as a textbook for students who have already had an introductory course of general zoology. It is unnecessary and even undesirable, from the point of view of the organisation of zoological courses in British Universities, that students who have not attained the intermediate standard should have separate textbooks of invertebrate and vertebrate zoology. It is manifestly impossible, so far as final and honours students are concerned, to

produce an adequate textbook of the Invertebrata in the space of 280 pages. We cannot, therefore, recommend the book for general use in this country.

F. W. R. B.

MEDICINE.

The Cambridge Medical School. By Sir HUMPHRY DAVEY ROLLESTON, Bart., G.C.V.O., K.C.B., M.D. [Pp. 235.] (Cambridge: At the University Press, 1932. Price 15*s*. net.)

A JOURNAL of medical science begins its booklet, issued to intending contributors, with a significant remark to the effect that it has no ambition to be recognised as a well of English undefiled. Its meaning may be obvious and its intentions admirable, but the spirit underlying the disavowal is worthy of comment. Medical literature is not only in danger of developing into uncouth jargon; it has lost all touch with the humanities. Medical education is so exhausting, rather than exhaustive, that medical men can scarcely claim to be educated. Yet there is a fine tradition of medical literature; from Sir Thomas Browne to Sir Clifford Albutt, to Sir William Osler, and to the present Regius Professor himself, experience has shown that physicians can be men of culture. Almost deliberately, to-day, medical men in authority drive their students, and their contributors, to a rather cold-blooded and illiterate monotone.

Sir Humphry Rolleston's book is timely. The authorities on medical education everywhere must face important decisions to-day. Medical degrees can now be obtained without, or with a minimum of, liberal education; doctors, literally " men who teach," are in danger of becoming artisans. At Cambridge, a Medical Science Tripos is being considered. An attempt is being made to enforce a course of broad-minded training, to make men face, if one may use a medical metaphor, the malignant edge of knowledge, where it invades the unknown. It is disheartening to teach the modern medical student, and to find him always asking, " What does authority say ? " and not asking, " Why does authority say so ? " ; and unless the universities of the country point the way there is little chance of the hospitals, driven to face the urgent clinical problems of each day, being able to induce a change of mind. It is true that the Oxford and Cambridge students do reach London with some dower of divine curiosity. But, alas, it is only too often a slender endowment.

This work is called a biographical study, and Cambridge men will welcome the sympathetic and vivid pictures of figures like those of Sir Michael Foster, Walter Gaskell, and Sir Clifford Albutt, whom so many remember; they will be glad to learn of the sturdy men of older generations who made the position of their university secure. But, for all the charm of anecdote and great though the value of this historical survey be, the lesson to be learned from these pages is something else.

There are great new laboratories; biochemistry, physiology, biophysics, pharmacology, bacteriology and pathology have decentralised medical education. The medical student of to-day wanders through these laboratories like a tourist attending a conducted visit to an industrial centre. When his " education " is over, and he makes his neophyte entry as a contributor to medicine, he is not yet, it is true, warned *Surtout pas trop de zèle*, but he is warned " No literary flights." Editors need not worry; he is incapable of them; the one thing of which he is terrified, faced by an apparently overwhelming mass of technical knowledge, is imagination.

The present Regius Professor, to the deep regret and the great loss of Cambridge men, is shortly to retire. He will leave his successor this work to show that the Cambridge Medical School has stood for something; and in his own self he has shown that a Cambridge medical graduate may not be a stranger to the humanities.

A courageous step may be necessary; but Cambridge, which has often taken the lead before, should not be afraid to cut a clear path through the tangles of medical education, and produce graduates who, perhaps, may know less, but may think more. A smaller school might produce greater men. After all, though men judge a tree by its fruits, quality is a consideration as well as numbers.

R. J. V. PULVERTAFT.

History of Scottish Medicine. By JOHN D. COMRIE, M.A., B.Sc., M.D., F.R.C.P. Second Edition. Two Volumes. [Pp. 852, with 2 plates and 404 illustrations in the text.] (London: Baillière, Tindall & Cox, for the Wellcome Historical Museum, 1932. Price 50*s*. net.)

ALTHOUGH nominally a fresh edition, this is actually a new work, so greatly has it been extended from the limited one-volume production that was issued to celebrate the inauguration of the section for Medical History at the British Medical Association Meeting held in Edinburgh in 1927. As it stands, it is a notable book which, within the limits the author has set himself, must be regarded as definitive. It may, as time goes on, be amplified, but it can never be superseded.

The place which Scotland has filled in the history of medicine is no insignificant one, and Dr. Comrie has exhaustively demonstrated this proposition without any appearance of conscious effort to emphasise the fact and with such a degree of inevitability as places his narrative well upon the plane of genius.

In the story of the subject during mediæval times again, there is much that sounds strange and curious to modern ears, yet through it all there runs a unity of steady evolution, progress, and development; and not all the early remedies were so absurd as at first sight they may appear, empirical knowledge regarding quite a number of them having to-day carried us not much farther beyond the practice of our distant ancestors when that practice has been seen distinctly, cleared of the religious and superstitious frills that generally obscured the essential aspects thereof.

Dr. Comrie's chapters on Gaelic Medicine are particularly interesting and appropriate, and his detailed and descriptive calendar of the various mediæval manuscripts available for reference in the great national and other libraries is a section whose value cannot be over-estimated. So, likewise, is the final short chapter in which are summarised, in clear and direct terms, the medical legislative changes in the nineteenth and early twentieth centuries. One feels, at times, that something more than the dry bones of many of the dead-and-gone controversies might have been displayed, for, not infrequently, it was by such that new light was brought to shine with complete and conclusive effect; but limits of space no doubt was the ruling factor there.

Altogether, apart from the letterpress, the volumes should have made a very respectable history of Scottish Medicine by means of the illustrations alone, the portrait gallery itself being as nearly complete as it were possible to be in such a work. Every school of Scottish Medicine—Edinburgh, Glasgow, Aberdeen, St. Andrews—is adequately represented.

WILLIAM SAUNDERS.

MISCELLANEOUS.

Photogrammetry: Collected Lectures and Essays. Edited by O. VON GRUBER, translated from the German by G. T. MCCAW and F. A. CAZALET. [Pp. xii + 454, with 353 illustrations and inset map.] (London: Chapman & Hall, 1932. Price 30*s*. net.)

THIS is not a book for casual readers.

The editor states that it has been compiled mainly from lectures delivered during the Vacation Course on Photogrammetry at Jena in 1929.

The selection of the chapters to be included was decided on the following principles:

(1) That they should be limited to the applications of Photogrammetry in the service of Topography.

(2) That they should provide a coherent review of the principles, methods, and instruments of Phototopography; and

(3) That they should include an examination of the relative efficiencies of various instruments and methods.

To indicate the scope of the work, perhaps it will be best to quote the headings of the chapters, viz.:

I. The Aims and Problems of Topographical Photogrammetry.
II. The Geometrical Bases of Photogrammetry.
VII. Ground Photogrammetry.
X. Stereoscopic Vision and Measurement.
XI. Automatic Plotting Apparatus.
XII. Operational Methods and Production, all by O. von Gruber, D.Ph.
III. The Rendering of Details in Photographs, by K. Grundlach.
IV. Some Zeiss Lenses for Photogrammetry, by W. Merté.
IX. The Development of Photogrammetry in the Light of Invention, by W. Sander.
V. Requirements for the Construction of Rotating Disc Shutters, and their Realisation; and
VI. The Zeiss Air Cameras, by H. Küppenbender.
VIII. A Portable Phototheodolite, and its use on the Alai-Palmar Expedition of 1928, by R. Finsterwalter.
XIII. The Efficacy of Photogrammetry for Precision and Economy, by L. Fritz.

Of the authors, it may be mentioned that the four first named are scientific members, in different sections, of the firm of Carl Zeiss, Jena; the fifth is constructional supervisor of the firm of Zeiss-Ikon, Dresden; while the two last named are, respectively, the lecturer in Geodesy and the Senior Professor of Geodesy, at the Technological High Schools of Hanover and Stuttgart.

From this list, it may be imagined that the book is written somewhat from the viewpoint of the firm of Zeiss. It is, however, nevertheless, undoubtedly a useful contribution to the scientific study of its subject.

Most of its chapters contains records of original research, and some of them are made up almost entirely of the results of such work.

The elaborate mathematical investigations in Chapter V (occupying forty-six pages), on Rotating Disc Shutters, are an example of the thoroughness with which the study has been carried out.

Chapter IX, on the development of Photogrammetry, is stated to have been written from the standpoint of a patent agent, and is, perhaps, the most interesting to the general reader, besides being one of the longest.

Chapter VIII contains only a very brief record of an interesting survey, and judging from the excellent photographs one could wish it had given a fuller account of the personal experiences of the party.

The translators state that the text of the original has been followed as closely as possible; and, indeed, it is difficult to avoid a wish that they had been less conscientious in this respect. The phraseology and the construction of sentences differ so much in the two languages, that (at all events to the present writer) it seems clear that a freer translation would have made the book less difficult for the English reader.

Most chapters conclude with tables of references, and the index and illustrations are excellent.

M. T. M. O.

Philosophy and the Ordinary Man. Presidential Address to the British Institute of Philosophy. By SIR HERBERT SAMUEL. [Pp. 39.] (London: Kegan Paul, Trench, Trübner & Co., Ltd., 1932. Price 1*s*. 6*d*. net.)

THIS address constitutes an eloquent plea to philosophers to drop their esoteric language and come down to the level of the ordinary man who now, more than ever, requires their help; in other words, to further the object for which the British Institute of Philosophy was founded.

From the point of view of the pure scientist, however, the importance of this booklet will consist of the fact that it contains a letter from Einstein written to the author on the subject of causality. During the last few years, as we know, the universe has been getting more and more mysterious, physics has been allied with mysticism, and even causality has been light-heartedly thrown overboard. All this time Einstein has said nothing. At last he has been persuaded to speak. Part of his letter must be quoted:

"Hitherto people have looked upon the Principle of Causality as a proposition which would in the course of years admit of experimental proof with an ever-increasing degree of exactitude. Positively defined as a limiting proposition, the principle runs as follows:

"The state (which can be ascertained as accurately as desired by observation) of an isolated system at time t_1 determines unequivocally the state of the system at every other time t_2.

"Now Heisenberg has discovered a flaw in the proposition, which deprives it in a certain sense of its content. It can be shown, that is to say, that the state of a system cannot as a matter of fact be exactly ascertained at all, because the observation necessarily influences the state of the system, and that not to as small a degree as one chooses, but in a finite degree that can be mathematically formulated. But if the state cannot be accurately ascertained, then the principle of causality loses its significance as an empirical proposition.

"Causality is thus only conceivable as a *Form of the theoretical system*. Now modern physicists are mainly of the opinion that it is inadmissible to build up any sort of theory on what cannot, in principle, be tested. They maintain therefore that a deterministic theory is to be rejected, and that it is merely conservatism based on custom and prejudices to search after such a theory. In this they go, in my opinion, too far.

"For the choice of a theory is determined by two points of view. It ought, firstly, to form a bridge between experienceable facts, and bring these into as many-sided a connection as possible. And, secondly, it ought to be built up on the simplest possible premisses. This last condition, however, seems to me to be only very inadequately fulfilled by the quantum theory in its present form, and this just because it rests on a theory of probability.

"It should be noted that every theory, even the present quantum theory, makes use of concepts which do not really admit of experimental tests. And so the postulate on which the exclusion of causality is based cannot be fulfilled at all."

—at once profound, scientific, concise, and epistemologically unassailable, qualities rare at any time, but particularly so at the present.

G. B. BROWN.

Ergebnisse und Probleme der Naturwissenschaften. By BERNHARD BAVINK. [Pp. viii + 616, with 88 illustrations.] (Leipzig: Verlag von S. Hirzel, 1930. Price 25 Marks.)

THIS is the fourth edition, now revised and enlarged, of a book which has had a wide popularity in Germany. It gives a survey of the results and chief theories of all the major branches of modern natural science. It is divided into four main divisions. The first deals with chemistry and physics, the

second with Astronomy and Cosmogony, the third with the biological sciences, and the fourth—as its title *Natur und Mensch* suggests—deals with the relations of human beings to one another and to the rest of nature. In spite of its wide range it is by no means a "popular" book in the sense in which that word is used by English publishers. It is essentially a book for the scientific reader who is interested in regarding his own science in its relation to others. There is no book in one volume in English which covers such a range of topics without superficiality. The author devotes a good deal of space to the logical and epistemological problems of modern science, especially in connection with physics. The English reader will find here a good introduction to the work of German writers in this field. In this connection Prof. Pavink opposes the Viennese school of Schlick, Carnap, and others, and defends the *Realist* standpoint. The book includes a very full bibliography, name-index and subject-index, and thirty-four pages of notes in which special problems are further discussed and other references given. Such a work deserves to be better known in England.

J. H. W.

Archæology in England and Wales, 1914–1931. By T. D. Kendrick, M.A., and C. F. C. Hawkes, M.A., F.S.A. [Pp. xix + 371.] (London: Methuen & Co. Price 18*s*. net.)

Archæology is now a highly specialised study with many branches, and it is doubtful if there are many, even among archæologists themselves, who realise how great has been the volume of discovery in England and Wales during the seventeen years covered by this book. Notwithstanding the concise treatment of both fact and theory, the authors occupy some three hundred and fifty pages, exclusive of sixteen pages of closely printed index, to give an account of the new material which has accrued in the time. Mere bulk, it is true, is no criterion of progress; but the discoveries range from prepalæolithic man to the Anglo-Saxons; and they include such important additions to knowledge as "Woodhenge" and "The Sanctuary," Windmill Hill, and the fort of St. Catherine's Hill, any one of which might alone suffice to mark a decade in archæological exploration as memorable.

The division of labour between the authors has been happy. Mr. Kendrick is responsible for the first eight chapters. He deals with prepalæolithic man, where he displays a commendable caution, the palæolithic, mesolithic, neolithic and early and middle Bronze Ages, adding chapters on "flint mines" and the "Henge" monuments, stone circles and rock-sculptures. Mr. Hawkes follows with the late Bronze Age, the early Iron Age, and Roman Britain. Mr. Kendrick writes the concluding chapter on the Anglo-Saxons.

Where so much is of high quality it would be invidious to select; yet the intricacy of the subject-matter, as well as intrinsic interest, give a special value to Mr. Hawkes's chapters on the late Bronze Age and the Iron Age, Mr. Kendrick's lucid exposition of the present position of the Stonehenge problem—still, as he says, a major problem of British archæology—and of the theories of the excavators of Woodhenge and the Sanctuary will be appreciated by those who have not had the opportunity of access to the original accounts of the work of exploration. Special interest also attaches to the chapter on the Anglo-Saxons, for in this period, as he has shown in his evening lecture to the Prehistoric Congress and elsewhere, Mr. Kendrick has it in mind to raise some pretty problems in the analysis of artistic origins and chronology.

It is of advantage to a science, especially when, like archæology, it advances by the analysis and comparative study of a multitude of details, that stock should be taken periodically. Our authors have here put their colleagues under an obligation by carrying out a task, which if not thankless must at least have had its tedious moments. For the general reader the interest and value of the book lie in the fact that not only does it bring him abreast of the

archæological knowledge of the day, but it equips him to follow future discovery with understanding. In this the very ample illustration—30 plates and 123 figures in the text—will assist materially.

E. N. Fallaize.

Wireless: A Treatise on the Theory and Practice of High-Frequency Electric Signalling. By L. B. Turner, M.A., M.I.E.E. [Pp. xviii + 528, with 31 plates and 342 diagrams.] (Cambridge University Press, 1931. Price 25*s*. net.)

In spite of the flood of books on the subject of wireless communication which has appeared in recent years, little has been done to supply the needs of the student equipped with the necessary groundwork of physical and mathematical knowledge who wishes to become acquainted with the principles of this new and important branch of applied science. This gap has now been filled by Mr. Turner in a highly satisfactory manner. The present book is a development of the author's *Outline of Wireless*, but so great has been the progress made during the intervening ten years that the new work bears little resemblance either in matter or in size to its predecessor; the greater part of it is now naturally devoted to the thermionic valve and its associated circuits, although the older methods have not been entirely ignored.

The subjects dealt with include the theory of electromagnetic radiation and of its propagation round the earth, oscillatory circuits, the production and detection of high-frequency currents, thermionic tubes and their use as amplifiers, oscillators, and rectifiers, telephony, antenna systems, filters and the nature of atmospherics. Some limits must obviously be set to a work of this sort, and the author has wisely refrained from entering on the wide field of radio-frequency measurements and the special problems of phototelegraphy and television. The book is, however, thoroughly up-to-date and includes such matters as screen-grid valves, frequency stabilisation by means of tuning-forks and quartz crystals, single side-band transmission, and beam antennæ. The problem of rectification is dealt with in considerable detail, including the case of linear detection at large amplitudes, the importance of which in the reception of modern deeply modulated broadcasting transmitters is now recognised. In the chapter on the valve oscillator the case of operation at high efficiency, where the limits of the linear characteristic are exceeded, is fully treated and clearly contrasted with the sinoidal régime, in which the efficiency is necessarily low; this should do much to remove misconceptions based on the over-simplified treatment frequently adopted.

The author writes in a lucid style and maintains throughout a very satisfactory balance between the physical, mathematical and engineering aspects of the subject. The numerous excellent diagrams contribute materially to the easy understanding of the text.

N. L. Y.-F.

The Skeletal Remains of Early Man. By Aleš Hrdlička. [Pp. viii + 379.] (Washington: Smithsonian Miscellaneous Collections, Vol. 83, July 1930.)

This volume is in effect an enlarged edition of a small treatise on *The Most Ancient Skeletal Remains of Man*, originally published in 1914 and reprinted two years later by the Smithsonian Institution. It has long been out of print, and the author accordingly has prepared the present volume in which, notwithstanding the change of title, the plan of the earlier work is retained. Its aim is to give reliable data, including as far as possible original observations and measurements, on the older and more valuable skeletal remains of man. It deals only with the remains of forms that differed substantially from those of later prehistoric time and those of the present. It closes,

therefore, after the detailed examination of individual specimens, with the consideration of the Neanderthal problem.

The later publication differs from the original, not merely by the inclusion of descriptions of the numerous finds which have been made since 1914, such as Rhodesian man, the Gibraltar child discovered by Miss Dorothy Garrod, the Galilee skull and the Rome skull, but there are added the results of repeated personal examination of the older material made since 1914. Indeed- one of the chief merits of the book is that it is so largely a record of the per, sonal observations, checked more than once, of so careful an observer as Dr. Hrdlička on both the old and the new material. Its claim to a permanent place on the anthropologist's reference shelf lies in its value as a repository of accurate and, so far as possible, complete information on the skeletal remains of early man.

It must not be assumed, however, that this is the book's only merit. With the part of the unbiased scientific observer, Dr. Hrdlička doubles that of the impartial judge before whom theory is brought to the test of evidence. His qualities as a ruthless critic, who exacts the utmost rigour of scientific proof before admitting an argument as conclusive, are here usefully exercised in testing theories which have sometimes been more bold than scientifically sound.

The theories of so logical a thinker and so cautious a critic carry double weight, even when they run counter to generally accepted views, as they do in the discussion of the Neanderthal problem, where Dr. Hrdlička argues that the modern type of man is directly descended from Neanderthal. It is unfortunate that at the time of writing the author had little before him relating to the then recently discovered Peking man, and, on the evidence which had reached him, could not regard it as other than Neanderthaloid. His comments on the conflicting views held on controversial points, which he presents in impartial summary, are always illuminating. Nor is he always content with their mere statement. On occasion he can take up a decided position himself on one side or the other, as, for instance, in regard to the relation of the femur and skull of pithecanthropus, the type of the Piltdown skull, and the relation of skeletal bones found in the Broken Hill mine to Rhodesian man.

The volume is illustrated by photographs and diagrams, many of them new. Whether the reader agrees with Dr. Hrdlička's views or not, it will always be a valued and helpful possession.

E. N. FALLAIZE.

Catalogue of Latin and Vernacular Alchemical Manuscripts in Great Britain and Ireland dating from before the Sixteenth Century. By DOROTHY WALEY SINGER, assisted by ANNIE ANDERSON. [Three vols. Pp. xxxi + 1179.] (Brussels: Union Académique Internationale, Palais des Académies, 1928–31. Price 40 Belgas.)

THIS catalogue appearing under the auspices of the Union Académique Internationale is a supplement to the catalogue of Greek Alchemical Manuscripts in the various countries of the world in course of publication by that body. It owes its origin to the devotion of Mrs. Singer to the cause of learning in that she has, for the benefit of other scholars, undertaken the labour of arranging in catalogue form the material she has collected over many years in connection with the history of mediæval science. The British Academy, as a contribution to the work of the Union Académique Internationale, has generously borne the cost of printing the work.

The number and variety of these early manuscripts preserved in England will probably come as a surprise to many interested in the early history of Chemistry, and this catalogue gives some indication of the vast amount of material available for research. Unfortunately, an adequate knowledge of

Latin and Chemistry is not commonly combined in one individual in these days, nor is research in the History of Science sufficiently encouraged in the universities, though London has done something in this direction in recent years. Until, however, work of this kind is considered at least as important and brings the same material rewards as the less-exacting experimental research, it is unlikely that a true appreciation of the knowledge of the earlier workers in Chemistry will be forthcoming.

There are six main divisions of the *Catalogue*: Greek and Arabic Alchemy in Prose, Western Alchemy in Prose, Anonymous Alchemical Prose Works, Alchemical Verse and Commentaries thereon, Chemical Crafts and Natural Magic, and Alchemical and Technical Recipes and Notes. These are followed by two appendices, and the work is very thoroughly indexed. Perhaps the most notable omission is a list of abbreviations which would have been of considerable use to some interested in the subject who are not familiar with the usual abbreviations of catalogues.

Mrs. Singer has greatly simplified the work of anyone anxious to throw new light on the fascinating subject of alchemy, and it is to be hoped that workers in this field will be forthcoming.

O. L. B.

Smoke: A Study of Aerial Disperse Systems. By R. Whytlaw-Gray, O.B.E., Ph.D., F.R.S., and H. S. Patterson, B.Sc. [Pp. viii + 192.] (London: E. Arnold & Co., 1932. Price 14*s*. net.)

"Suddenly it all seemed as smoke to Litvinov, seated in a railway train, everything, his own life, everything human. All steam and smoke, he thought; all seems for ever changing, on all sides new forms, phantoms flying after phantoms, while in reality it is all the same and the same again; everything hurrying, flying towards something and everything vanishing without a trace, attaining to nothing; another wind blows and all is dashing in the opposite direction, and there again the same untiring, restless and useless gambols." The authors, in this book, have a very different philosophy to that of Turgenev, who wrote the novel bearing the same title. They have made smoke give up some of its secrets, so that to a physical chemist it will no longer be a conjurer of memories, but another subject to be added to the curriculum.

The major thesis of this monograph is directed towards the measurement of changes occurring in "smokes" as they coagulate on ageing, and fascinating photographs are shown of the formation of daisy-chain clusters of cadmium-oxide smoke contrasted with the gradual tadpole-like growth of *m*-xylene-azo-β-naphthol smoke. They show that the theory of Smoluchovski, designed to account for coagulation in colloidal systems, can be modified to be suitable for this ageing effect in "smokes."

The classical experiments on the charge on an electron are cleverly modified to yield information about the number, size and density of smoke particles. A chapter is devoted to photophoresis, or the behaviour which some particles show of moving either towards or away from the source of a beam of light. By setting two light beams at an angle the particles can be made to turn corners. Another chapter gives a very thorough experimental and theoretical treatment of the scattering of light by "smokes" and shows conclusively why previous work on coagulation of "smokes" was incorrect. In a chapter on the electrification of "smokes" it is shown that very different characteristics are obtained depending on whether the initial charge is slight or high. A smoke formed by unipolar electrostatic brush discharge tended to form a curious spherical cluster in the centre of the smoke chamber. The book concludes with a chapter on the evaporation of small droplets and by enumerating a number of problems which still remain to be solved.

The authors discard the theory of von Weimarn of nuclei formation, as having little application to "smokes," since the temperature during dispersal

is gradually changing. Surely an ammonium-chloride smoke can be produced which would not have this disadvantage, and would allow the application of an experimental test ?

This book, in developing an exact experimental technique for the study of "smokes," should give an impetus to their study and elucidation, at least in so far as to bring our knowledge of them on to the same footing as other colloidal systems. It should form an excellent foundation for chemical engineering research work ; on the one hand, for the adequate removal of all "smokes," whether from the combustion of fuel or from chemical reactions, which now pollute our atmosphere ; and, on the other hand, for the preparation of stable smoke screens or the production of such compounds as zinc oxide in controlled degrees of fineness.

M. B. DONALD.

Southern Europe. By MARION I. NEWBIGIN, D.Sc. [Pp. 515.] (London : Methuen & Co., 1932. Price 21*s*. net.)

THIS work is a regional and economic geography of six countries of Southern Europe—Spain and Portugal, Italy and Switzerland, Greece and Albania. There is a very useful bibliography at the end of each section ; this indicates the author's debt to continental geographers and geologists from whose works she draws freely, thereby rendering real service to those English students who are not familiar with this extensive literature. But for the smaller work on the Mediterranean Lands which Miss Newbigin brought out eight years ago, this is the first important work on its region in English ; and it is at once indispensable to all students of the geography of Europe.

Structural evolution, as a help to the interpretation of geographical features, is given chief place in this volume. In the regional sections this is followed by accounts of relief, details of frontiers, natural divisions, and climate, leading to the human geography, *i.e.* communications, population, and products.

The book is certainly "close reading" as the author says in her preface. One frequently feels lost in a welter of detail ; though there is an attempt to prevent this by occasional brief summaries of the argument. There is also a marked lack of general map-diagrams. In the section on general climate maps of the rainfall distributions, and of the climatic regions adopted, would have been of great assistance to the reader. But there are no such maps in the book. And, although the work is primarily a regional geography, the limits of the "natural divisions" used are often left vague ; and in only one case, the Iberian Peninsula, is there a map to show them. In the occasional use of very long involved sentences (*e.g.* at the bottom of p. 74) and the relative lack of diagrams this book falls far below the high standard of clarity to which Miss Newbigin has accustomed her readers. We may hope that the second edition, which will probably be required soon, will be revised from this point of view.

R. E. D.

A Book of General Science. By M. J. HILTON. [Pp. 399 and 157, with illustrations.] (Toronto : The Macmillan Co., 1931. Price 7*s*. 6*d*.)

THIS textbook of general science has been authorised by the Ministers of Education for Alberta and British Columbia and is, apparently, intended to be a basis upon which the teacher can build up his own course. The teaching throughout is kept in close touch with daily life, and teachers of science in schools will find many valuable hints. Some of the terms used are strange to English readers, as, for instance, "teeter" for "see-saw." The book should find a place in the school library for special reading.

W. C. BROWN.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Projective Differential Geometry of Curves and Surfaces. By Ernest Preston Lane. Professor of Mathematics in the University of Chicago. Chicago, U.S.A.: The University of Chicago Press. (Pp. xi + 321.) Price 22*s*. net.

The Universe of Science. By H. Levy, Professor of Mathematics at the Imperial College of Science, University of London. London: Watts & Co., 5 Johnson's Court, Fleet Street, E.C.4. (Pp. xiii + 224.) Price 7*s*. 6*d*. net.

Mathematical Tables. Volume II. London: Office of the British Association, Burlington House, W.1., 1932. (Pp. viii + 34.)

The Theory of Functions. By E. C. Titchmarsh, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford. Oxford: at the Clarendon Press, 1932. (Pp. x + 454.) Price 25*s*. net.

Matriculation Trigonometry. By Clement V. Durell, M.A., Senior Mathematical Master, Winchester College. London: G. Bell & Sons, 1932. (Pp. viii + 151.) Price 3*s*. 6*d*. net.

Plane Algebraic Curves. By Harold Hilton, M.A., D.Sc., Professor of Mathematics in the University of London. Second Edition. London: Oxford University Press, 1932. (Pp. xv + 390.) Price 28*s*. net.

Linear Transformations in Hilbert Space and their Applications to Analysis. By Marshall Harvey Stone, Associate Professor in Yale University. American Mathematical Society Colloquium Publications, Volume XV. New York: American Mathematical Society, 501 West 116th Street, 1932. (Pp. viii + 622.) Price $6.50.

The Calculation of Heat Transmission. By Margaret Fishenden, D.Sc., F.Inst.P., and Owen A. Saunders, M.A., M.Sc. London: His Majesty's Stationery Office, 1932. (Pp. xii + 280.) Price 10*s*. 6*d*. net.

Physikalisch-Chemisches Taschenbuch unter Mitwirkung Zahlreicher Fachgenossen. Herausgegeben von C. Drucker und E. Proskauer. Band I. Leipzig: Akademische Verlags Gesellschaft m.b.H. 1932. (Pp. viii + 546 with 292 figures.) Price 27.50 M. Bound, 29 M.

Tables of Cubic Crystal Structure of Elements and Compounds. By I. E. Knaggs, Ph.D., and B. Karlik, Ph.D. With a Section on Alloys by C. F. Elam, M.A., D.Sc. London: Adam Hilger, 98 Kings Road, Camden Road, N.W.1, 1932. (Pp. 90.) Price 11*s*. 6*d*. net.

Electrical Phenomena in Gases. By Karl Kelchner Darrow, Ph.D., Research Physicist, Bell Telephone Laboratories. London: Baillière, Tindall & Cox, 8 Henrietta Street, W.C.2, 1932. (Pp. xvii + 492, with 91 figures and 4 plates.) Price 42*s*. net.

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The Psychology of Animals in Relation to Human Psychology. By F. Alverdes, Professor of Zoology, University of Marburg. London: Kegan Paul, Trench, Trübner & Co., 68 Carter Lane, E.C., 1932. (Pp. viii + 156.) Price 9*s*. net.

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The Last Cruise of the Carnegie. By J. Harland Paul, Surgeon and Observer. With a Foreword by John A. Fleming, Acting Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington. Baltimore, U.S.A.: The Williams & Wilkins Company, 1932. London: Baillière, Tindall & Cox, 8 Henrietta Street, W.C.2. (Pp. xvii + 311, with 198 figures.) Price 26s. 6d. net.

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The Exponential and Hyperbolic Functions and their Applications. A Practical Book for the General Student and Engineer. By A. H. Bell, B.Sc., Principal of Sheerness Technical Institute. London: Sir Isaac Pitman & Sons, 1932. (Pp. x + 81.) Price 3*s*. 6*d*. net.

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John Thomas Gulick, Evolutionist and Missionary. Portrayed through Documents and Discussions. By Addison Gulick. Chicago, Illinois, U.S.A.: University of Chicago Press; London: Cambridge University Press. (Pp. xvi + 556, with 3 plates and 41 figures.) Price 22*s*. net.

Kosmos. A Course of Six Lectures on the Development of our Insight into the Structure of the Universe, delivered for the Lavell Institute in Boston, in November 1931. By W. de Sitter, Director of the Observatory and Professor of Astronomy at the University of Leiden. Cambridge, Massachusetts, U.S.A.: Harvard University Press, 1932. (Pp. xii + 138, with 11 figures and 12 plates.) Price $1.75.

Convegni Biologici 1° Convegno: Biologia Marina, Napoli—Dicembre, 1931. Consiglio Nazionale delle Ricerche. Comitato Nazionale per la Biologia. Napoli: Premiato Stab, Tipografico Nicola Couvene, Donnalbina 14. Instituto di Chimica Biologica della R. Universita, Via Constantinopoli 16, 1932. (Pp. 147.) Price L.15

Do you speak Chimpanzee? An Introduction to the Study of the Speech of Animals and of Primitive Men. By Georg Schwidetzky. London: George Routledge & Sons, Carter Lane, E.C.4. (Pp. viii + 133.) Price 6*s*. net.

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The Anatomy of Modern Science. An Introduction to the Scientific Philosophy of To-day. By Bernhard Bavink. Translated from the 4th German Edition, with additional notes and Bibliography for English Readers by H. Stafford Hatfield. London: G. Bell & Sons, 1932. (Pp. xiii + 683, with 87 figures and 12 plates.) Price 21s. net.

Abstracts of Dissertations for the Degree of Doctor of Philosophy. Vol. V. (1931–2). University of Oxford Committee for Advanced Studies. Oxford: at the Clarendon Press, 1932. (Pp. 121.) Price 3s. net.

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Objektive Spektralphotometrie von Dr. L. S. Ornstein, Dr. W. J. H. Moll, Dr. H. C. Burger. Braunschweig: Friedr. Vieweg & Sohn, Akt.-Ges., 1932. (Pp. vi + 146, with 75 figures.) Price 10.80 R.M.

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SCIENCE PROGRESS

RECENT ADVANCES IN SCIENCE

APPLIED MATHEMATICS. By Prof. F. E. Relton, D.Sc., M.A., Royal School of Engineering, Giza.

Hydrodynamics.—The air of irreality that hangs over certain branches of this subject is nowhere more noticeable than in our discussion of two-dimensional problems. The omission of one of three co-ordinates might, at first sight, be expected to obviate an immense amount of complexity. No doubt it does; but even with this modification, the discussion of a comparatively simple-looking problem makes very considerable demands on our knowledge of pure mathematics. How much more, therefore, may we expect the difficulties to increase when we attempt to make rigorous discussion of the corresponding problems in three dimensions. The two-dimensional case has the immense advantage of bringing to hand all our knowledge of the complex variable and conformal representation. It does at least give us a chance to make some sort of attempt on problems involving rigid boundaries and free stream lines, though nobody can regard the limitation to a plane as anything but a *pis aller*.

When we attempt the three-dimensional problems, there is no powerful general method, analogous to conformal representation, to come to our aid. We are accordingly thrown back on some special system of co-ordinates, and reduced to choosing the problem to fit the answer. The procedure seems inevitable until some very decisive advance has been made in related branches of pure mathematics, notably in the realm of partial differential equations, of which our knowledge is depressingly small.

The foregoing remarks are well illustrated by a phenomenon in fluid motion with which we are all familiar from infancy—the jet of liquid. With a wealth of higher mathematics, and after stripping the problem of every semblance of reality, Helmholtz solved the analogue of the parallel-plate condenser. Since then, numerous allied questions have been treated, with rigid boundaries and free stream lines; but the exact solution of

the three-dimensional problem of the fluid jet seems as far off as ever. In default, one naturally turns to some sort of approximative method, and this brings me to a group of five papers which have recently appeared.

V. Volterra writes, " Sur les jets liquides " (*J. Math. pures appl.*, vol. IX, **11**, 1–35), in a paper that falls into two sections. First premising the existence of a force potential, and taking the free boundary surface as known, he derives the differential equation of the velocity distribution on the surface. This is interesting because the stream lines coincide with the trajectories of particles moving freely on the boundary surface. When this surface happens to be one of rotation, considerable progress can be made. The second part is taken up with the determination of the velocity inside the jet, and with the search for a possible rigid boundary. The work is carried out approximatively when the free surface and the rigid boundary are not too disparate.

There is a sequel to Volterra's work, the reference being the same as before (pp. 57–66), in a " Contribution à l'étude des jets fluides," by Joseph Pérès. The approximative methods of Volterra are here applied to the case where the boundary surface is not of revolution. The intervening pp. 37–56 are occupied by T. Levi-Civita, " Sur les jets liquides," which is best taken in conjunction with another paper by the same author " Sui getti liquidi " (*Rend. Semin. mat. fis., Milano*, **5**, 154–173). These two papers set out to find a treatment which shall accord reasonably well with the known experimental results. They differ from ordinary potential-theory methods in much the same way that the simplified beam theory differs from academic elasticity. What the author denotes by a " linear condition " corresponds to an average over the cross-section of the fluid jet, considered as thin. It then remains to define some curve as the middle line, possibly variable with time. Under certain reasonable assumptions concerning the pressure distribution over the cross-section, equations can be derived which have the form of the equations for the motion of a perfectly flexible, inextensible string. In the steady state they coincide with these latter, and lead to the corresponding catenary. The test experiments confirm this result for the beginning of the stream, which widens later and describes its free path, parabolic in the gravitational field.

A corollary to the foregoing work was given by G. Lampariello, " Sulle equazioni differenziali di Levi-Civita nel problema dei getti liquidi " (*Atti Accad. naz. Lincei, Rend.*, vol. VI, **14**, 556–60). This is essentially pure mathematics, being concerned with the existence of regular solutions of the

system; the question is closely related to the equation of heat conduction.

Three papers, on two-dimensional vortex motion, have sufficient affinities to make it possible to group them together. W. B. Morton writes "On the Motion near Two Straight Parallel Vortices" (*Proc. Roy. Irish Acad.*, A **41**, 1–7). Rosario Cormagi writes on the "Azioni dinamiche esercitate in un moto piano liquido provocato da vortici liberi in un semipiano" (*Note Esercit. Mat.*, **6**, 255–9); whilst another Italian, Bruto Caldonazzo, has a more ambitious effort, "Sui moti liquidi piani con un vortice libero" (*Rend. Circ. mat. Palermo*, **55**, 369–94). In a higher category than these, there is work on the finite vortex from the pen of J. Rossignol, "Problème touchant des tourbillons cylindriques de section finie" (*C.R. Acad. Sci., Paris*, **194**, 2026–8). This is a continuation of some earlier work, published in the preceding volume of the same journal. The former work consisted in the derivation of a pair of integral equations on which the solution of the problem depended; the present work deals with the solution of these by successive approximation.

Elasticity.—It is a pity, in some ways, that certain branches of mathematics failed to develop in a different order. One can see that it would have been an advantage if vector analysis and tensor calculus had established a footing earlier. As things are at present, they give to all except the very young the impression of having arrived at the circus after the show is over. They accordingly have to justify their late appearance, to the older ones, by performing all the old tricks more neatly than the clumsier Cartesian analysis could do. Most of the standard textbooks, such as those on elasticity and fluid motion, whose reputations have slowly built themselves up over a generation and which are based on Cartesian methods, will no doubt never be rewritten on modern lines. It would be too much like pouring new wine into old bottles. We may, therefore, expect to see the gradual appearance of monographs and booklets, treating these and allied subjects on modern lines, with the gradual supersession of the present standard works.

What form will the booklets take? No doubt vector analysis will occupy the earlier stages; but what of the later stages? For most of the theoretical work on viscous motion and elasticity the treatment by dyadics suffices. In reality, very few writers use the dyadic idea except when specifically writing on vector analysis. The tendency is now for writers to utilise the longer ranged tensor calculus. This is noticeable in Richard Gans's *Vector Analysis*, where tensors are introduced but dyadics not mentioned. Tensor calculus is now part

of the normal course in mathematics at the French higher polytechnics.

One such production as I have mentioned is by Jean Villay, "Introduction à l'étude de la résistance des matériaux" (*Mem. Sci. physiques Fasc.*, **21**, 1–76). In contradistinction to the other fascicules that have appeared in this collection, it is less a conspectus of the present state of our knowledge of the subject than an introduction to the mathematical groundwork of elasticity and its connection with strength of materials. The first three chapters are concerned with the stress and strain tensors, and their connection through the laws of elasticity. Three further chapters are concerned with beam theory, and two with statically indeterminate problems ; a final chapter adverts to the significance of the theory of plasticity, a subject which will be treated more fully in a future issue.

A piece of work, chiefly of theoretical interest, is by Angelo Tonolo, "Sui sistemi isostatici con sforzi costanti di un mezzo elastico in equilibrio" (*Ann. Scuola norm. super. Pisa*, vol. II, **1**, 277–82). Postulating the absence of body forces, and adopting the hypothesis that the principal stresses are invariant with position, the problem is to find all the triply orthogonal families of surfaces whose intersections give the principal axes of stress. Apparently there is no restriction when the principal stresses are all equal ; when no two are equal, the only possible surfaces are planes.

The question of isostatic systems is further discussed, by the same author, in a manner that takes cognisance of space-curvature. The source is "Sistemi isostatici dei corpi elastici negli spazi a curvatura costante" (*Semin. mat. Univ. Padova*, **2**, 152–63). The fundamental assumptions are much as before ; the conclusions, for a space of positive curvature, exclude the existence of media wherein the stresses are all different and pointwise invariant. Space of negative curvature admits of one of the three principal stresses being zero, the other two being equal and opposite.

Those who are interested in problems relating to shafts will remember Howland's recent paper in the *Phil. Mag.* and Robertson's criticism in the same journal ; I mentioned both in my last article. I now have to draw attention to a number of allied papers. Rembold and Jehlicka are brief in "Resonanzausschläge bei Drehschwingungen von Kurbelwellen" (*Z. Ver. Deutsch. Ing.*, **1**, 480–2). R. Grammel's work on "Die erzwungenen Drehschwingungen von Kurbelwellen" (*Ing. Arch.*, **3**, 76–88) is a continuation of what appeared under his name in the previous volume of the same journal. In American literature we have C. R. Soderberg "On the Sub-critical Speeds of the Rotating Shaft" (*Amer. Soc. Mech. Eng.*, **54**, 45–52) ; but

the longest effort comes from France and is the work of Th. Got, " Contribution à l'étude des vitesses critiques de flexion des arbres tournants " (*J. Ec. polytech.*, vol. II, **29**, 7–53). Substantially this is a discussion of Dunkerley's empirical formula and the theoretical basis on which it can be placed. In a test case, fully worked out, the original Dunkerley formula affords a better approximation than that given by Hahn's modification. Dunkerley's work appeared in *Phil. Trans.*, **185**, 279–360, and has twice previously been examined by Got. The references are : " Sur le calcul des vitesses critiques des arbres tournants de section constante et de masse non négligeable portant des disques minces parfaitement centrés " (*C. r. Acad. Sci. Paris*, **193**, 706–8, 1931) ; " Sur la valeur des formules de Dunkerley et analogues pour le calcul approché de la première vitesse critique de flexion d'un arbre tournant," in the same volume of the same journal, pp. 836–9. Some of this latter work has now been criticised by P. E. Brunelli, " Intorno ad alcuni valori singolari delle velocità critiche degli alberi " (*Atti Accad. naz. Lincei, Rend.*, vol. VI, **15**, 43–6). Finally, we have S. Gradstein, " Erzwungene Torsionsschwingungen von Kurbelwellen " (*Ing.-Arch.*, **3**, 206–14).

The torsion of a beam, in which are embedded circular pieces with different elastic constants, as in reinforced concrete, has been discussed on the usual Saint-Venant hypothesis by N. Mouskhelichvili, " Sur le problème de torsion des poutres élastiques composées " (*C. R. Acad. Sci., Paris*, **194**, 1435–7). In a different category there is W. J. Duncan's paper, " On the Torsion of Cylinders of Symmetrical Section " (*Proc. Roy. Soc.*, A **136**, 95–113). The fundamental idea is to develop the torsion function in powers of a parameter, and to find the coefficients by successive approximation. The solution for related cross-sections can be derived by variation of the parameter ; the work is carried out for four types of cross-section.

Mechanics.—Most of the problems on motion in a resisting medium resolve themselves, very soon, into exercises on the integration of differential equations. The question of whether a particular case shall be discussed or not is usually decided by the facility with which the equation can be integrated. A slight attempt to give something more general has been made by G. Doubochine, writing in *Russ. astron. J.*, **9**, pp. 7–19 and 20–6. The papers are in Russian ; the first, on motion in a resisting medium, takes a central Newtonian force and a resistance which is an arbitrary function of the velocity and the density. The solution then depends on two quasi-integral equations. The second paper discusses a particular case ; a solution is derivable when the resistance is directly proportional to the velocity and the density.

It hardly seemed likely that anything strikingly new could be said, at this time of day, about the momental ellipsoid. Those who read D. Wolkowitsch's "Applications de l'ellipsoïde d'inertie" (*C. R. Acad. Sci. Paris*, **184**, 534–6) will find nothing in it dynamically new; but the fact that a rigid body can be represented, by either an ellipsoid or a tetrahedron of equal mass, leads to interesting geometrical connections between these two configurations.

A distinctly less informative piece of work is by E. R. Lowenstern on "The Stabilising Effect of Imposed Oscillations of High Frequency on a Dynamical System" (*Phil. Mag.*, vol. VII, **13**, 458–86). The analysis is plain, straightforward, Lagrangian equation stuff; the applications are to a pendulum, two jointed rods, and three jointed rods, with a moving point of support. It seems rather meagre fare to put into print; at least, it could have been improved by reference to Kelvin's discussion of the problem in general, given in *Proc. Roy. Soc.*, A **50**, 194–200 (1892).

The finite number of degrees of freedom of a dynamical system is a fixture, irrespective of whatever system of co-ordinates is adopted. The number of independent co-ordinates is the same as the number of degrees of freedom; but it is sometimes an advantage to take the number of working co-ordinates in excess of this. The corresponding modifications in the equations of motion have been discussed by C. A. Shook, "An Extension of Lagrange's Equations" (*Bull. Amer. Math. Soc.*, **33**, 135–44). He replaces the n variables q by $n + 1$ variables r, and derives $n + 1$ Lagrangian equations of motion, postulating the vanishing of the derivative of the kinetic potential with respect to the excess velocity-component. A goemetrical interpretation is given for the case where $n = 2$. The generalisation is to a system with n degrees of freedom expressed in terms of $n + p$ variables; application is made to a problem in planetary theory.

The reverse process, of reducing the number of equations, has recently been discussed by G. D. Mattioli, "Sulla riduzione di rango dei sistemi canonici mediante integrali generici" (*Atti Accad. naz. Lincei, Rend.*, vol. VI, **15**, 437–43). If we have a canonical system with $2n$ variables, and we know m integrals in involution, we can reduce to a canonical system with $2(n - m)$ variables, with a system of m differential equations in addition. The procedure to be adopted, when the m integrals include the energy-integral and are not in involution, is the problem which the author discusses. The integration constants are used to replace m of the impulse co-ordinates, the canonical system being regarded as the Pfaffian system for the relevant linear differential form. This leads to a com-

pletely integrable system of $2(n-m)+s$ differential equations, to which is added a set of $(m-s)$ differential equations. If it happens that the m integrals form a function group, in Lie's sense, the first of these systems can be given a canonical form, a system with $2(n-m+\mu)$ variables, together with a system of $m-2\mu$ equations.

The discussion of the problem of the top, either under no forces or under gravity, soon resolves itself into the study of elliptic and hyperelliptic functions. The asymmetrical top under no forces, and the symmetrical top under gravity, may be considered as solved completely. The asymmetrical top under gravity has been discussed approximatively, in two particular cases, by Grammel. This gives interest to a recent paper by Hans Gebelein, "Über den unsymmetrischen, schweren Kreisel" (*Ann. Physik*, vol. V, **12**, 889–926). The actual integration of the equations of motion is, of course, at present out of the question; but the author has treated the problem approximatively by perturbation-theory methods in an interesting manner.

The last paper to which I wish to direct attention is, strictly speaking, not about mechanics but algebra; but it is related to mechanics sufficiently closely to warrant it being mentioned here. In my last article I remarked upon a lengthy paper by the Russian writer, A. Krylov, dealing with the determination of the periods in a system with numerous degrees of freedom. He has given a method of writing the determinantal equation in such form that the parameter occurs only in the first column, a fact which makes the determinant easy to develop. His work has been followed by another Russian, writing in the same journal, N. Luzin, "On Krylov's Method of writing the Secular Equation" (*Isv. Akad. Nauk. S.S.S.R., Otdel. mat. i estest. Nauk*, vol. VII, **7**, 903–58). Luzin's object is to find a purely algebraic foundation and interpretation for this new and practical method. He admits that his memoir has not exhausted the subject, and opines that the subject is, in some way, bound up with Liapounov's theory of the stability of motion.

MATHEMATICAL PHYSICS. By Prof. G. Temple, Ph.D., D.Sc., University of London, King's College.

The survey of Eddington's research in the quantum theory contained in the last number of Science Progress requires to be completed by a reference to his latest paper on "The Theory of Electric Charge" (*Proc. Roy. Soc., A.*, **138**, 17, 1932). This paper amends, simplifies, and co-ordinates the results of earlier papers in a most striking manner.

The argument may be summarised as follows: According

to Fermi and Dirac the wave function for a pair of electrons must be anti-symmetrical in their co-ordinates. If x and x' summarise the co-ordinates of the electrons, the pair of electrons is represented in their eight-dimensional co-ordinate space either by the point (x, x') or by the complementary point (x', x). The direct intercharge of x and x' is a discontinuous transformation, but it can be obtained by a series of continuous transformations if (x, x') and (x', x) are connected by a path passing outside the original co-ordinate space. If displacements along this path are measured by a cyclic co-ordinate χ which increases from 0 to π as (x, x') becomes (x', x), then the momentum M_χ conjugate to χ must find a place in the wave-equation, in order that probability may be conserved in this fictitious displacement as well as in real displacement of x and x'. It is shown that the corresponding term in the wave-equation agrees in form with the interaction energy, and a further agreement indicates the value of the fine structure constant.

The theory centres round the operator P, which is defined in the notation of the previous article by the equation,

$$P = \frac{1}{4i} \Sigma F_\mu F'_\mu.$$

Then $P^2 = -1$, and the two sets F_μ, F'_μ are connected by the relation $F'_\mu = -PF_\mu P$.

The symmetrical and anti-symmetrical operations $\gamma_{\mu\nu}$ and $\zeta_{\mu\nu}$ are transformed according to the law,

$$P\gamma_{\mu\nu} = \gamma_{\mu\nu}P \text{ and } P\zeta_{\mu\nu} = -\zeta_{\mu\nu}P,$$

whence $$\gamma'_{\mu\nu} = \gamma_{\mu\nu} \text{ and } \zeta'_{\mu\nu} = -\zeta_{\mu\nu}.$$

Let $\psi_{\alpha\beta}(x, x')$ be the wave-equation for the two electrons. Then $P\psi_{\alpha\beta} = \iota\psi_{\beta\alpha}$.

We now replace the discontinuous transformation with operator P by the group of continuous transformations with operator,

$$K(x) = \exp \tfrac{1}{2}(P + \iota)\chi.$$

When $$\chi = \pi, \; K(x) = \iota P,$$

and $$K(x) \cdot \psi_{\alpha\beta}(x, x') = -\psi_{\beta\alpha}(x', x),$$

the momentum operator M_χ conjugate to χ is given by the equation,

$$K(\chi) = \exp(\chi M_\chi).$$

Since $\exp(\pi M_\chi) \cdot \psi = -\psi = \exp(2n+1)\iota\pi$, the proper values of M_χ are of the form $\iota(2n+1)$.

The corresponding term in the wave-equation will presumably have a similar form to the terms,

$$(E_{23}M_{23} + E_{31}M_{31} + E_{12}M_{12}),$$

involving the standard angular momenta,

$$M_{23} = x_2P_3 - x_3P_2, \text{ etc.}$$

Hence it will have the form $(P + \iota)M\chi/r_\chi$, the denomination r_χ measuring the radius of curvature of the path of the fictitious displacement. r_χ will evidently be proportional to r_{12}, the distance between the electrons, and M_χ can be replaced in general by $\iota(2n + 1)$, and usually by its lowest quantum number ι. Moreover ιP can be factorised as follows :

$$\iota P = \iota P_1 \cdot \iota P_2,$$

where $\iota P_1 = \frac{1}{2}(-1 + E_{23}E'_{23} + E_{31}E'_{31} + E_{12}E'_{12}),$

and $\iota P_2 = \frac{1}{2}(-1 + E_4E'_4 + E_5E'_5 + E_{45}E_{45}').$

$-\iota P_1$ is Dirac's interaction operation $\frac{1}{2}(1 + \sigma \cdot \sigma')$, and ιP_2 will usually (either accurately or approximately) be quantised with proper values ± 1. Hence the interaction term in the wave-equation will be proportional to $(1 \pm P)/r_{12}$. (The term r_{12}^{-1} can easily be removed by a simple transformation.)

The identification of the numerical constant multiplying this term depends upon the transformation of " ψ – densities," analogous to tension densities, and uses an agreement similar to that considered in Eddington's previous papers.

PHYSICS. By L. F. Bates, B.Sc., Ph.D., F.Inst.P., University College, London.

British Contributions.—Until the publication of a very interesting paper by Rao and Badami (*Proc. Roy. Soc.*, **138**A, p. 540, 1932), only three lines of the Lyman series of hydrogen had been photographed. In their paper a beautiful photograph of fifteen lines of this series is given. The record was obtained by the use of a discharge tube with a hollow cathode. The latter consisted of a carbon tube closed at one end. Near the closed end some metallic arsenic could be confined by a perforated plate, so that arsenic vapour might enter the tube through the perforations.

The open end of the cathode faced a vacuum spectrograph, and helium was circulated through the apparatus. Hydrogen was not introduced into the apparatus from an external source, and any present occurred as an impurity in the helium. When no arsenic was present, fifteen lines of the Lyman series were excited, the intensity of the lines decreasing with increase in term number.

A peculiar anomaly in the intensity distribution was observed when arsenic was present. The intensity of the tenth and eleventh members of the series was considerably increased, whilst the higher members practically disappeared. It is suggested that this is an example of "sensitised fluorescence," the enhancement of members of the Lyman series being due to energy transferred to the hydrogen atoms by collisions of the second kind with arsenic atoms.

It is considered that an ionised and excited arsenic atom in the metastable $4p^2\,{}^1S_0$ state may collide with a normal hydrogen atom and an electron, to produce a hydrogen atom in the $11p$ state and a normal arsenic atom. It will be remembered that Duffendack and Smith (*Phys. Rev.*, **34**, p. 68, 1929) showed that by collision with an excited rare gas atom A', a normal molecule B might be simultaneously ionised and excited—thus: $A' + B = A + B^{+'} +$ electron. The experiments of Rao and Badami presumably establish, for the first time, the occurrence of the reverse process.

In two recent papers, by Tyndall and Powell (*Proc. Roy. Soc.*, **136**A, p. 145, 1932) and Powell and Brata (*Proc. Roy. Soc.*, **138**A, 117, 1932), an account is given of the determination of the mobilities of ions of all the alkali metals in the gases helium, neon, argon, krypton, xenon, nitrogen, and hydrogen by the four-gauze method, a method of high resolving power, suitable for the separation of ions of slightly different mobilities. Interesting comparisons of the experimental values with those deduced from the formulæ of Langevin and Hasse are made.

Langevin assumed that the ions and molecules might be regarded as elastic spheres with an inverse fifth power force between them. This force was attributed to the polarisation of the molecules by the ions. He found that the mobility k of an ion was given by the expression,

$$k = \frac{A}{\sqrt{\rho(D-1)}}\,[1 + m/M]^{1/2},$$

where ρ is the density of the gas, D the dielectric constant, M the mass of an ion, m the mass of a molecule, and A is a function of the sum of the radii or the closest distance of approach of an ion and a molecule in a collision, and of the polarisability of the molecule.

Hasse replaced this elastic sphere model by one of point centres with attractive and repulsive forces. This results in the replacement of the constant A in Langevin's expression by a constant which varies with the relative magnitude of these attractive and repulsive forces. When the gas is highly polarisable, *i.e.* the attractive forces are strong, the two con-

stants become practically identical and equal to 0·51, if k is expressed in cm. per sec. per unit electrostatic field.

A series of curves is therefore obtained by plotting the experimental values of the mobilities of the alkali ions against the corresponding values of $[1 + m/M]^{1/2}$ for the several gases. The experimental points do not lie on the Langevin curve in the cases of helium and neon, but this curve fairly well corresponds to the experimental results with argon, krypton, and xenon, the respective values of A being 0·54, 0·55, and 0·56. The deviations from the curve in the cases of helium and neon are precisely of the nature predicted by theory, for the relative values of the polarisabilities of argon, neon, and helium are approximately 8, 2, and 1 respectively. The remarkable agreement between the calculated and experimental values in the cases of the heavier rare gases suggests that in the majority of the collisions between ions and atoms the attractive forces due to polarisation predominate.

Similar experiments carried out with neon give a value of A equal to 0·48 ; here, however, definite signs of clustering due to the presence of polar impurities are found, unless relatively low pressures obtain. The main impurity is found to be ammonia, and ions formed by the addition of one, two, and three molecules of ammonia were identified by their mobilities. It is purposed to add polar impurities in known amounts to the rare gases and to study the average number of collisions which occur before attachment takes place.

An attempt has been made to detect the existence of the two isotopes of lithium by the difference in their mobilities. Some little success has resulted, and it suggests the possibility of a method of concentrating Li_6 atoms. A search for the missing element, 87, ekacaesium, using the mineral samarskite (cf. Papish, *J. Amer. Chem. Soc.*, **53**, p. 3818, 1931) with the four-gauze method, has been unsuccessful.

McLennan, Burton, Pitt, and Wilhelm (*Proc. Roy. Soc.*, **138**A, p. 245, 1932) have extended their experiments on superconductivity, using alternating currents of high frequency. To ensure that all the superconductor was under the influence of the alternating current, a tin specimen was used in the form of a thin layer " wiped " upon a constantan wire, so that it formed a tube with a thickness very small compared with its diameter. Consequently, the skin effect of the alternating current extended over the whole of the specimen.

The direct-current resistance of the tin was measured at various temperatures, both with and without the accompaniment of high-frequency currents, and the alternating-current resistance was measured with and without the addition of direct current. It was definitely established that the critical

point, *i.e.* the temperature at which the resistance becomes too small to measure, for direct-current resistance was lowered by the application of high-frequency current, and that the critical point for alternating-current resistance was raised by the presence of a direct current.

German Contributions.—An attractive piece of research is described by O. Betz (*Ann. der Phys.*, **15**, p. 321, 1932), who has measured the absorption of damped electromagnetic waves of wavelengths 3 to 30 cm. in ionised hydrogen, oxygen, and nitrogen. He used a linear oscillator whose efficiency was enormously increased by the use of liquid air as dielectric. The latter kept the oscillator cool, while the escaping gas cleaned it.

The oscillator was placed at the focus of a concave mirror and an iron-constantan vacuum thermo-element was placed at the focus of a similar mirror. Waves from the oscillator left the first mirror in a parallel beam, were reflected by a plane mirror on to the second concave mirror, which focused them on to the thermo-element. The plane mirror was in two symmetrical portions, one of which could be displaced in the direction of the incident rays. Hence, interference maxima and minima could be produced at the focus of the second concave mirror. The absorbing gas was confined in a glass bulb 20 cm. in diameter, at whose centre the thermo-element was situated.

In the case of hydrogen—the ionisation was produced by the type of long tube used by R. W. Wood—selective absorption maxima were found for wavelengths of 3, 9, and 28 cm. These wavelengths were found to be independent of the degree of ionisation of the gas. They agree as well as can be expected with the values calculated from the fine structure levels of the hydrogen atom, for the transitions $2p_1 - 2s$, $2d_2 - 3p_2$, $3p_1 - 3s$, and $3d_1 - 3p_1$ respectively correspond to wavelengths of 2·74, 9·25, 9·25, and 27·75 cm.

In an interesting paper on the investigation of the magnetostriction of alloys of iron and nickel, F. Lichtenberger (*Ann. der Phys.*, **15**, p. 45, 1932) describes a method of preparing single crystals of these alloys. Vacuum smelted electrolytic iron and nickel wires 0·5 mm. in diameter were cut into equal lengths and melted together in a quartz tube 2 to 4 mm. wide in an induction furnace. By choosing the relative numbers of nickel and of iron wires an alloy of known composition could be obtained. Attempts to prepare single crystals by the Bridgeman method were frequently unsuccessful because of the supercooling of the alloys, particularly when the latter were rich in nickel. This was overcome by fixing an efficient vibrator to the top of the quartz tube holder. The effective shaking produced the nuclei necessary for the commencement of solidi-

fication, and in no wise disturbed further growth; indeed, even under the influence of powerful shaking, pure single nickel crystals were obtained.

The magnetostriction of each alloy was measured by the variation in the capacity of a condenser, which formed part of a heterodyne circuit, and of which one plate was fixed to the specimen—when the specimen changed its length on change of magnetisation. The magnetisation curve was also obtained for each specimen, and Lichtenberger considered very carefully the correction for demagnetisation. One or two of his specimens were single crystals in the form of tubes, so that by putting a small test solenoid inside the middle of a tube, the field actually acting upon the specimen in this region could be found.

The direction of easiest magnetisation is found to be the [100] for alloys with 30 to 71 per cent. nickel, and the [111] for alloys with 71 to 100 per cent. nickel. The reason for the striking behaviour of the alloy generally known as permalloy, which contains about 78 per cent. nickel, is probably that its composition represents the most satisfactory mean between the composition of 71 per cent. nickel, at which the change in the direction of easiest magnetisation occurs, the composition of 83 per cent. nickel for which polycrystalline magnetostriction disappears, and the composition of 85·5 per cent. nickel for which magnetostriction is equal in all directions.

A series of important contributions to the study of the diffusion of liquids has recently emanated from Prague (*vide Zeit. für Phys.*, **79**, pp. 275–345, 1932). They owe their existence to a new apparatus designed by Zuber for rapid work with colourless liquids. To one of the adjacent sides of a right-angled prism a narrow glass trough is cemented, so that in contact with the side of the prism a vertical film of liquid can be placed. The glass trough forms the diffusion chamber and a thin horizontal lamina divides it into two portions. The lower portion is filled with the liquid whose diffusion coefficient is required, and the upper with the solvent.

The lamina is removed and light from a mercury arc is passed through a suitable filter and collimator on to the hypotenuse of the prism. The latter is set so that light just passes through the glass-liquid boundary to emerge through the narrow side of the trough. Consequently, as viewed through a microscope the field is divided into a bright and a dark portion separated by an oblique curved line, which gradually (in the microscope field) moves upwards as diffusion proceeds. The position of a convenient point on the line of separation, corresponding to the point of total reflection, is observed at stated times, and thus the rate of diffusion is directly measured. As a microscope is employed, it is sufficient to record observations

for about half an hour, in contrast to earlier methods which require intervals of time measured in weeks.

It is found that solutions of electrically neutral liquids and solutions of electrolytes obey the Boltzmann diffusion law in all cases so far investigated. The variation of the diffusion coefficient with concentration is determined by a graphical method. In the case of solutions of the alkali halides the coefficient first decreases with increase in concentration and then increases, characteristic kinks being recorded at certain concentrations. The theoretical aspects of these results are examined at length by Sitte.

An interesting estimation of the energy required to disrupt a lead crystal has been made by Hevesy, Seith, and Keil (*Zeit. für Phys.*, **79**, p. 197, 1932) by finding the temperature variation of the coefficient of diffusion of an isotope of lead, Thorium B, into a single crystal of lead. The Thorium B was condensed on to the surface of the crystal, and the variation of its α-ray activity with time provided a measure of the diffusion of the radioactive substance into the lead, for any α-particles liberated inside the lead will lose energy in emerging from it.

The diffusion coefficient D is given by the expression $A \cdot e^{-Q/RT}$, where A is a constant which is practically independent of the absolute temperature T and Q is the heat of disruption of the lead crystal. Consequently, log D should vary linearly with T, and the slope of the line should give Q. The latter was in this way found equal to 27,830 cal. per mol., and both A and Q were found not to depend on the crystalline structure. With lower values of T it was possible to check the results obtained above by measuring the number of recoil atoms emitted by the Thorium B at stated times. These measurements were rather more definite because of the extremely small range of the recoil atoms in lead compared with the range of the α-rays in the metal.

The results of Ramsauer have long accustomed us to the ease with which very slow electrons may pass through rare gases—almost as if the latter were not present—but we have so far had little evidence that electrons may move with such freedom in a discharge tube. Consequently, some new experiments of Güntherschulze and Keller (*Zeit. für Phys.*, **77**, p. 703, 1932) on glow discharges in rare gases are worthy of note.

They produced their discharges in a spherical glass vessel 40 cm. in diameter, in which the cathode was a piece of magnesium supported in the middle of the vessel by a glass-sheathed iron wire. The anode was a sputtered coating of magnesium covering practically the whole of the inner surface of the vessel, so that no disturbances arose from charges upon its walls. The positive column was thus about 18 cm. long.

According to Schottky's theory, the potential gradient in the positive column is inversely proportional to the radius of the discharge tube and independent of the pressure. Thus, when r is very large, the gradient should be very small, which means that a very small difference of potential is required to maintain the positive column. Since, other things being equal, the current i in a discharge tube is inversely proportional to the square of the pressure p, experiments were carried out at various pressures and the voltage applied to the tube was plotted against i/p^2.

Except for very low currents, the curves thus obtained showed but a slight gradient. Since the applied voltage is the sum of the anode fall, the fall in the positive column and the cathode fall, conditions were chosen under which the anode fall remained practically constant whilst the cathode fall varied but little. The results then showed that in the case of argon over a range of pressure for 2·8 to 46·3 mm., and of neon up to 28·8 mm., the applied potential was constant to about 1 per cent. Hence, the normal gradient in the positive column must be considered zero, *i.e.* the gases may be said to possess a kind of superconductivity, which reminds us of the Ramsauer effect.

A very small gradient was found in the positive column in helium. This was possibly due to the pressure of impurities, and it is regarded as probable that helium behaves in the same way as argon and neon. In the case of hydrogen, a normal gradient of 2·40 volts per cm. per mm. pressure was found, in good agreement with earlier results.

The Gyromagnetic Effect.—In a paper, entitled " Eine neue Methode zur Messung des Einstein-de Haas-Effektes " (*Helv. Phys. Acta,* V, p. 217, 1932), F. Coeterier and P. Scherrer discuss the defects of the resonance method of measuring the gyromagnetic ratio, and they describe a new method which avoids the disturbing action of any horizontal component of the vertical magnetising coil upon any horizontal component of the magnetic moment of the vertical specimen in their experiments.

As is well known, when a ferromagnetic rod changes its magnetic moment by an amount M it simultaneously receives angular momentum of amount U about the axis of magnetisation, given by the equation $U/M = \frac{1}{g} . 2m/e$, where g is the Landé splitting factor, and e and m are respectively the charge and mass of the electron. When the motion of the electron responsible for ferromagnetism is purely orbital, $g = 1$, and for a spinning electron, $g = 2$.

To describe the new method of measuring U/M, we shall

first suppose that an iron rod or wire hangs vertically from the end of a quartz fibre, so that the iron is entirely within a vertical solenoid. If the latter is supplied with alternating current of frequency $2\pi/w$, the magnetic moment of the iron at any instant, t, is given by $M = M_0 \sin (w \cdot t)$, whilst it experiences a gyromagnetic couple $\frac{1}{g} \cdot \frac{2m}{e} \cdot w . M_0 \cdot \cos (w \cdot t)$.

The effect of the disturbing action outlined above is to produce an additional couple proportional to sin $(w.t)$ acting upon the iron. Consequently, the oscillations of the suspended system will be slightly out of phase with the magnetisation, and its displacement will be given by an expression of the form $a \cdot \sin (\omega \cdot t + \delta)$, where a is a constant. Therefore, if δ is made equal to zero, it is clear that the above disturbing action has been eliminated. This is done as follows.

A small mirror is mounted on the iron so that a very narrow beam of light may be thrown on to a scale at whose mid-point there is a slit of the same width as that of the beam of light. Hence, when the specimen oscillates, a beam of light passes through the slit every time the specimen passes through its equilibrium position. The emergent light activates a photo-electric cell and relay system which reverses a direct current in the solenoid, and thus reverses the magnetisation.

Although the disturbance is now brought into phase with the vibration itself, it need not necessarily be completely eliminated. Elimination is only completely attained when there is no shift of zero when the magnetising field acts on the system. Consequently, the cause of the disturbance must be reduced as much as possible by other known means to prevent the shift of zero. When this is done, the damping may be greatly reduced and the resonance amplitude accordingly increased. From the resonance amplitude the value of U can then be calculated.

It is claimed that if the solenoid current is reversed with sufficient sharpness, the sources of error of previous methods are absent, and that the new method is easier to use. As a test of the method, a provisional measurement of g for iron has been made, and the value 2·01 obtained. This is in excellent agreement with the value 2·00 obtained at Bristol, but it does not so well agree with the value 1·89 obtained by Barnett in America. It is therefore to be hoped that the authors will soon be able to give us their final value for this constant. The writer of this article understands that recent work reported from India also supports the Bristol value. He is unable to accept Barnett's reasons for the discrepancy between the two values, and he looks forward to the publication of further results.

GEOLOGY. By G. W. Tyrrell, A.R.C.Sc., D.Sc., University, Glasgow.

Sedimentation and Sedimentary Rocks.—W. H. Twenhofel's Presidential Address to the Geological Society of America on "Environment in Sedimentation and Stratigraphy" (*Bull. Geol. Soc. Amer.*, **42**, 1931, pp. 407–24) emphasises the fact that sediments are responses to environmental conditions operating at the locus of deposition on characters inherited from parent rocks and previous processes. A point of some importance which is frequently overlooked is the distinction between the influence of environmental factors on living organisms in relation to deposition and that on the dead remains of organisms. After death organic matter becomes subject to the factors controlling inorganic sedimentation. Twenhofel draws the conclusion that stratigraphical correlation on the basis of fossils alone "is not entitled to a great deal of respect."

In his paper on "Die marinen Sedimente als Abbildung ihrer Umwelt und ihre Auswertung durch die regional-statistische Methode," O. Pratje (*Fortschr. d. Geol. u. Pål.*, Bd. 11, Deecke Festschrift, 1932, pp. 220–44), on the basis of his recent oceanographical work, seeks to evaluate certain factors in the deposition of marine sediments, such as the contributed materials, the distributing media, the relief of the sea floor, the compositional variations of sea water, and the influence of plants and animals. The characters thus acquired may serve to indicate the environment under which the sediments were laid down.

A paper on "Subaqueous Slides," by A. Hadding (*Geol. För. Förh., Stockholm*, **53**, 1931, pp. 377–93), deals with the occurrence, causes, results, and stratigraphical significance of sedimentary material which owes its main features to slipping down the plane of deposition on a sloping sea or lake floor. Abnormal deformed strata, with edgewise conglomerates, beds with flow structures, and beds enclosing balls with spiral structure, are the results of this action.

In a paper entitled "Ueber die Schichtung und ihre Bedingungen," R. Brinkmann (*Fortschr. d. Geol. u. Pål.*, Bd. 11, Deecke Festschrift, 1932, pp. 187–219) attempts a genetic classification of stratification. He distinguishes two main classes: (1) Primary sedimentary stratification, and (2) posthumous or diagenetic stratification. The former is divided into ten subclasses as follows: primary, graded, rhythmic precipitation, biogenic, current, tidal, climatic, volcanic, direct tectonic, and indirect tectonic bedding. Diagenetic stratification includes induction bedding (inhomogeneity produced in lower part of stratum by processes starting from upper surface), diagenetic bedding (due to dehydration and compression), and

reaction bedding (in which diagenetic redeposition and precipitation starts from primary stratification).

In a paper on "Non-glacial Marine Varves," W. H. Bradley (*Amer. Journ. Sci.*, XXII, 1931, pp. 318–30) states that the term "varve," which has almost come to imply a glacial origin for rhythmically laminated sediments, was originally proposed by G. de Geer as an international term for banded deposits showing an annual rhythm regardless of their origin. He has recently examined under the microscope several American Palæozoic marine laminated siltstones, and suggests that couplets of their laminæ, consisting of one dark and one light lamina, are probably marine analogues of non-glacial varves now forming in the sediments of certain fresh-water lakes.

W. D. Mark has described what appear to be the fossil impressions of ice crystals in strand sediments of Upper Bonneville age in Utah (*Journ. Geol.*, XL, 1932, pp. 171–6). These markings are entirely similar to those observed to form naturally on surfaces of saturated loess. Fossil ice markings, if sufficiently discriminated from other markings, may serve as a criterion for the identification of the tops of strata.

The *rillensteine* of German geologists are limestones bearing a grooved or channelled pattern in which the individual grooves are not more than a millimetre broad. J. D. Laudermilk and A. O. Woodford have studied this structure in American examples, and have performed experiments bearing on its origin (*Amer. Journ. Sci.*, XXIII, 1932, pp. 135–54). They have come to the conclusion that the grooving is almost certainly produced by solution, the work of the infrequent rains of an arid region.

L. Kolbl has investigated the grain size of fluviatile and æolian sediments by elutriation methods, and finds that a distinction between the two on the basis of grain-size distribution is possible only in fine sandy sediments (*Min. u. Petr. Mitt.* (*N.F.*), Bd. 41, 1931, pp. 129–44).

The deep-water deposits of the Red Sea have been studied by Z. Sujkowski (*Geol. Mag.*, LXIX, 1932, pp. 311–14). The influence of the surrounding deserts is reflected in these sediments by the abundance of rock-forming minerals such as amphiboles, pyroxenes, biotite, soda-lime and potash feldspars, and feldspathoids (*sic*), which are not common in ordinary detrital sediments. The common heavy minerals, such as zircon, rutile, garnet, and tourmaline, are rare or absent, and quartz occurs in comparatively small amount. Rounded grains are completely absent; and the author deprecates the use of the occurrence of rounded grains in marine sediments as proof of desert shores.

J. D. Laudermilk reports field and microscopical observa-

tions, and chemical analyses, of the dark brown and black incrustations of iron and manganese oxides, known as "desert varnish," from the Mojave desert of California (*Amer. Journ. Sci.*, XXI, 1931, pp. 51–66). The new data indicate that lichens are sometimes operative in producing desert varnish by the secretion of acid solutions.

Starting from the investigation of two great dust storms of the year 1928 in Poland and New Zealand respectively, K. Leuchs (*Centr. f. Min., Abt. B.*, 1932, pp. 145–56) tries to evaluate the significance of this phenomenon in sedimentation. He thinks that a layer of red clay in the Main Norian Dolomite Series of the Alps may be attributed with some probability to dust-storm origin.

From an exhaustive study of glauconite and glauconitic rocks in Sweden, A. Hadding (*Lunds Univ. Arsskrift, N.F. Avd.* 2, Bd. 28, 1932, 175 pp.) goes on to a complete discussion of the origin and palæogeographical significance of that mineral. He summarises the matter in the statement that glauconite always indicates sub-littoral shallow marine conditions and agitated waters. As a rule it is formed during periods of diminished sedimentation, and often during "negative" sedimentation, being most abundant immediately after such periods. Hence glauconitic rocks are frequently found associated with intraformational conglomerates and with phosphorites. Glauconite is never formed in an oxidising environment, nor under conditions which favour the existence of heat-requiring animals. Dr. Hadding also deals fully with the mineralogy and paragenesis of glauconite, and discusses the history of opinion concerning its origin.

The record of algal limestone of Permo-Carboniferous age from Queensland by H. C. Richards and W. H. Bryan (*Geol. Mag.*, LXIX, 1932, pp. 289–301) appears to be the first from that state, and in point of age from the Australian continent. A mass of limestone several miles in length and 1,100 feet thick is made up almost entirely of algal remains new to science, although having some resemblance to *Mitcheldeania* from the British Carboniferous.

In his work entitled "Beitrag zur Thema Dolomitenstehung," O. Bär (*Centr. f. Min., Abt. A.*, 1932, pp. 46–62), from physico-chemical considerations, seeks to establish the view that dolomitic formations are sometimes due to primary precipitation of this mineral.

F. H. Edmunds and R. J. Schaffer have written an excellent summary of the geology, petrology, and properties as building-stone of Portland stone (*Proc. Geol. Assoc.*, XLIII, 1932, pp. 225–40).

In describing the agate and chert of Derbyshire, P. Jessop

(*Proc. Geol. Assoc.*, XLII, 1931, pp. 29–43) makes use of the terms ortho-, meta-, and para-chert respectively, to indicate three genetic types. Ortho-chert was formed from colloidal silica contemporaneously with the enclosing limestones; meta-chert, the most common variety, is a replacement of the limestones, the silica having probably been derived from the adjacent limestone; para-chert is a late replacement due to silica solutions, and, unlike the meta-cherts, has no structural relation to the limestones.

Writing of the "Anhydrites and Associated Inclusions in the Permian Limestones of West Texas," J. E. Adams (*Journ. Geol.*, XL, 1932, pp. 30–45) states that the non-clastic sediments of this formation consist of marine limestones, dolomites, and "evaporites" (anhydrite, halite, etc.) in ascending order. The dolomite, which is largely an altered marine limestone, contains massive inclusions, "phenocrysts," aggregates, vein and cavity fillings, and fossil replacements of anhydrite, of which all save the two last-named appear to be of primary origin.

Pancake-shaped concretions composed mainly of manganese dioxide have been found in a small fresh-water lake in Nova Scotia, and are described by E. M. Kindle (*Amer. Journ. Sci.*, XXIV, 1932, pp. 496–504). These are of great interest, as they are the only known examples of manganiferous concretions which are being developed in a lacustrine environment. It is suggested that the reducing action of diatoms rather than bacteria on the manganese bicarbonate dissolved in the lake waters has produced the concretions.

G. E. L. Carter has described an interesting occurrence of vanadiniferous nodules in the Permian beds of South Devon (*Min. Mag.*, XXII, 1931, pp. 699–713).

In his William Menelaus Memorial Lecture on "The Geological History of Coal" (*Proc. S. Wales Inst. Eng.*, XLVI, 1931, pp. 911–51) Prof. G. Hickling has given a remarkably valuable little treatise on coal formation. He deals with the geological conditions necessary for the deposition of coal, evidence of earth movement in Carboniferous times, characters of Coal Measure vegetation, vegetable constituents of coal, ash content of various coal types and its commercial significance, and finally, the regional distribution of coal as evidence of progressive alteration. Pressure and rise of temperature have been the main factors in the formation of anthracite, but these would not have become operative had not the coal been buried under a substantial cover of later deposits. Hence the weight of cover is regarded as the vital factor.

Dr. C. S. Fox's memoir on "The Natural History of Indian Coal" (*Mem. Geol. Surv. India*, LVII, 1931, 283 pp.) really amounts to a comprehensive treatise on the modes of occurrence,

physical and chemical characters, and origin of coal in general, although based on Indian examples. The memoir is illustrated by a number of fine plates.

In two papers, "Classification and Development of Carbonaceous Minerals" (*Proc. Roy. Soc. Edin.*, LI, 1931, pp. 54–62), and "Graphical Classification of Carbonaceous Minerals: The Place of the Constituents of Common Coal" (*Ibid.*, LII, 1932, pp. 195–9), Prof. H. Briggs shows that if ultimate analyses of coals and carbonaceous minerals are reduced to terms of carbon, oxygen, and hydrogen only, and if carbon be then plotted against oxygen, a series of straight lines are obtained, one for each mineral species, including fusain, durain, vitrain, sub-cannel, cannel, oil-shale, and torbanite. These lines indicate the development of the several species from low rank (*i.e.* low C, high O) to high rank (*i.e.* high C, low O) minerals, and show that the process of evolution brings each mineral to a final product whose composition can be expressed by a simple formula of the type C_mH_{2n}. Thus the end product of the torbanite group will be $C_{4n}H_{2n}$, of fusain $C_{14n}H_{2n}$, etc.

The detailed study of Ordovician grits from Anglesey by E. Greenly and P. G. H. Boswell has thrown light not only on Ordovician palæogeography, but also on the tectonics of the older rocks (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, pp. 297–311). The Arenig grits of Berw were found to be exceptionally rich in heavy minerals, especially garnet, sphene, and epidote. Their poor grading, variable texture, and angularity of grain point to the close proximity of the source of the sediments. The acid gneisses of the Mona Complex are regarded as the main source, and it is thought that these gneisses must have overlain the basic gneisses, all but a narrow strip having been destroyed.

The Ordovician sandstones of Arkansas, described by A. W. Giles (*Journ. Geol.*, XL, 1932, pp. 97–118), have been altered since their formation by the deposition of silica forming crusts and crystal faces upon the original rounded and frosted grains. This secondary enlargement of the grains has conferred coherence upon the sandstones, diminished their porosity, and has thereby affected their capacity as reservoirs for oil or water.

H. Udluft has attempted to discriminate between greywackes, sandstones, and quartzites, utilising Devonian examples from German localities (*Sitz.-Ber. d. Preuss. Geol. Landesanst.*, 6, 1931, pp. 128–36. Also see *Geol. Centralbl.*, 47, 1932, pp. 84–6). He finds that the nature of the cementing materials affords the best criterion.

The Triassic sandstones of Yorkshire and Durham have been investigated by F. Smithson (*Proc. Geol. Assoc.*, XLII, 1931, pp. 125–56), who finds that the mineral composition affords

evidence of transport under arid conditions from regions of acid igneous rocks and metamorphic rocks, which may be identified with Caledonian and Armorican land masses. There is abundance of apatite in many of the sediments.

One of the results of R. Weyl's work entitled " Studien zur vergleichenden Sedimentpetrographie des norddeutschen Tertiärmeere " (*Centr. f. Min., Abt. B.*, 1932, pp. 157–63) is that the smallest additions to the heavy mineral content of the sediments took place at or a little later than the principal periods of coal formation.

J. D. Solomon's investigation of the heavy mineral assemblages of the Great Chalky Boulder Clay of East Anglia (*Geol. Mag.*, LXIX, 1932, pp. 314–20) shows that this deposit is characterised by great abundance of limonite, which distinguishes it from the North Sea Drift. The limonite must have come from some deposit below the Chalk escarpment, probably the Carstones ; the abundant garnet, which is associated with amphiboles, epidote, and andalusite, seems, however, to have been derived from the Crag. Mr. Solomon thinks that, with the aid of a prospecting pan, it should be possible to distinguish in the field between the deposits of the various glacial episodes in East Anglia.

In a paper on " Garnet-bearing Sands of the Northumberland Coast," L. Hawkes and J. A. Smythe (*Geol. Mag.*, LXVIII, 1931, pp. 345–61) contribute much new mineralogical and chemical data to the subject. The bulk of the sand is derived from the waste of Carboniferous sediments, partly through the mediation of glacial drifts. The Whin Sill contributes but little to the finer sands in its neighbourhood, and that mostly in the form, not of mineral, but of rock grains.

Metamorphism and Metamorphic Rocks.—An excellent short summary of the principles of metamorphism is given by Prof. P. Niggli in an article for the second edition of a German dictionary of science (*Handwörterbuch der Naturwiss.*, Bd. VI, 1932, pp. 901–15).

In a paper on " The Principles of Metamorphic Differentiation," Prof. P. Eskola attempts to outline some general physico-chemical principles whereby to explain concentrations in metamorphic rocks which do not come under the head of metasomatism (*C.R. Soc. Géol. de Finlande*, No. 5, 1932, pp. 68–77). Metamorphic differentiation may take place by the growth of crystals or aggregates of crystals (the concretion principle), by the concentration of the least soluble substances (the principle of enrichment in the most stable constituents), and the extraction and re-deposition of the most soluble substances (the solution principle). Eskola has apparently overlooked work by A. Harker and F. L. Stillwell on similar subjects.

An adequate summary of P. Eskola's masterly memoir on "Conditions during the Earliest Geological Times as Indicated by the Archæan Rocks" (*Ann. Acad. Sci. Fennicæ, Ser. A*, XXXVI, No. 4, 1932, 74 pp.) would require far more space than is available. Eskola deals with the varved schists and carbon-bearing schists of the Finnish Archæan, the value of Archæan argillaceous sediments as indicators of conditions of deposition, the leptite problem and the crystallisation-differentiation theory applied to acid volcanic rocks, changes of composition in metamorphism and the principles of metamorphic differentiation, and magnesia metasomatism. The memoir closes with a discussion of the beginnings of geological history as revealed in the rocks. Eskola concludes that many Archæan sediments were closely similar to certain Pleistocene sediments and that similar conditions of origin, *i.e.* weathering and deposition in temperate or cold climates, must be inferred.

The Lewisian complex of the island of Coll has been described by E. B. Bailey, V. A. Eyles, and J. B. Simpson (in "The Geology of Ardnamurchan, North-west Mull, and Coll," *Mem. Geol. Surv. Scotland*, 1930, Chapter II, pp. 4–27) as an inter-banded series of ortho- and para-gneisses. Metamorphosed calc-alkali igneous rocks of basic, intermediate, and acid characters, with predominant hornblende-biotite-gneiss, are well represented, along with quartzose granulites, biotite granulites, and magnesian marbles, which are derived from arkoses, impure sandstones, and impure dolomitic limestones respectively. Six new chemical analyses of these rocks are given.

Prof. H. H. Read's "Geology of Central Sutherland" (*Mem. Geol. Surv. Scotland, Expl. of Shs.* 108 *and* 109, 1931, 238 pp.) was unquestionably the outstanding memoir of 1931 in metamorphic geology. The main rock-group of the region is the Moine Gneiss Series, which occurs in three metamorphic facies: (1) the normal granulitic facies in which the pelitic types are garnetiferous and occasionally carry staurolite; (2) the injection facies, in which most of the rock types are garnetiferous and the pelitic varieties sillimanite-bearing; and (3) the dislocation facies, adjacent to the Moint Thrust. There are also large lenticular masses of rocks of Lewisian types. The most characteristic features of the area are injection-complexes in which granitic material has penetrated the country rocks in bewildering variety of structure, with the resultant formation of innumerable varieties of modified and mixed rocks. The injection is considered to have taken place during or immediately after the impression of the general metamorphism of the Moine and associated rocks, when high temperatures prevailed over large areas and directed pressures were operative.

Under these conditions the separation of a volatile-rich phase and the injection of thin sheets and veins from an unexposed granite mass were possible over enormous distances.

While the greater part of H. G. Backlund's memoir on "Das Alter des 'Metamorphen Komplexes' von Franz Josef Fjord in Ost-Grönland" (*Medd. om Grönland*, 87, No. 4, 1932, 119 pp.) deals with the age and stratigraphical relations of the metamorphic rocks of East Greenland, there is also a valuable account of injection metamorphism which is ascribed to the action of Caledonian granites. The metamorphic recrystallisation of the sediments increases concomitantly with increasing frequency of granitic dikes, and the type of recrystallisation is that due to contact action under penumatolytic influence, with addition to the affected rocks of alkalis, magnesia and ferrous iron oxide, and boron (tourmaline). These observations have an important bearing on the disputed question of the age of the "metamorphic complexes."

J. D. H. Wiseman, however, in a paper entitled "A Contribution to the Petrology of the Metamorphic Rocks of East Greenland" (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, pp. 312–49), states that two of the three fully described metamorphic complexes from the same region are composed of orthogneisses, paragneisses, paraschists, orthoschists, plagioclase-amphibolites, and occasional igneous rocks, and the metamorphism is therefore of the regional type. The metamorphism is believed by Wiseman to have no connection with assimilation of sediments by Caledonian granites, and there is some evidence of its pre-Cambrian age. An "Eastern Metamorphic Complex," however, does consist mainly of rocks showing an intimate interpenetration of granite magma into biotite-schist, but the age of this complex is doubtful. A point of contact may perhaps here be established between the conflicting Scandinavian and British views on the age of the metamorphism.

Prof. H. H. Read discusses the origin of corundum-spinel xenoliths which are enclosed in the gabbro of Haddo House, Aberdeenshire (*Geol. Mag.*, LXVIII, 1931, pp. 446–53). They belong to the silica-poor members of the argillaceous-calcareous group of hornfelses. These "emery" xenoliths have been described from other localities, but are of distinctly limited occurrence. They have been regarded as due to the metamorphism of boles or lateritic rocks, but the general association of emery xenoliths with horites leads Prof. Read to ascribe both rock types to mutual reactive transfer between basaltic magma and aluminous sediments, the reaction being arrested before its final stage is reached.

On the other hand, J. L. Gillson and J. E. A. Kania, in their paper on "Genesis of the Emery Deposits near Peekskill, New

York" (*Econ. Geol.*, XXV, 1930, pp. 506–27), dispute the conclusions of Bowen (and Read) in regard to the origin of emery rocks. The Peekskill occurrences were formed from an argillaceous schist in contact with norite. The norite is modified only at its margins, and much of the emery is found so far within the adjacent country rock that it could not have been formed by magmatic reaction. The authors conclude that the emery is of contact-metamorphic origin, produced by fluid emanations from the magma reservoir which passed up through the already solid border of the igneous mass, and into the schists, depositing the ore minerals in both endo- and exo-morphic contact zones.

A. G. MacGregor has compared the pyroxene-granulite hornfelses produced by contact metamorphism of basic igneous rocks around the Kainozoic igneous centres of Western Scotland (*Geol. Mag.*, LXVIII, 1931, pp. 506–21) with the beerbachites and gabbro-porphyrites of the Odenwald which, before the recent work of Klemm, were regarded as gabbro-aplite and pegmatite dikes. Klemm has now shown that these Odenwald types represent hornfelsed inclusions in the Frankenstein gabbro, but he regards the original material as of sedimentary origin. The chemical, mineralogical, and textural evidence which MacGregor brings forward shows conclusively that the Odenwald granulites were due to the thermal metamorphism of basic igneous rocks.

Contact-metamorphism in south-eastern Dartmoor, according to A. A. Fitch (*Quart. Journ. Geol. Soc.*, LXXXVIII, 1932, pp. 576–609), has affected a varied series of rocks, including Culm slates and sandstones, Carboniferous dolerite, Devonian slates, limestones, and igneous rocks of the spilitic series. These rocks have been acted upon by two distinct metamorphic agencies: first, dynamic metamorphism due to Armorican earth movements, and second, contact metamorphism due to the intrusion of the Dartmoor Granite. The latter can be subdivided into true thermal effects and chemical effects due to emanations from the granite. Under these circumstances an extraordinarily varied suite of metamorphic rocks has been produced, amongst the most interesting of which are skarns formed from limestones which closely resemble the typical Scandinavian occurrences.

Dr. G. D. Osborne has described the metamorphic limestones and associated contaminated igneous rocks of the Carlingford District, co. Louth (*Geol. Mag.*, LXIX, 1932, pp. 209–33) in considerable detail. In addition to such types as forsterite-brucite-spinel marbles, pure marbles, and calc-magnesian-silicate rocks due to ordinary thermal metamorphism, there are some very interesting rocks which have been affected by pneumatolytic action, especially custerite-monticellite rocks, and

andradite-wollastonite-hedenbergite skarns. Pegmatites containing the three last-named minerals are regarded as due to the reaction of pegmatite magma with adjacent skarns.

Dr. Osborne has also dealt with the contact metamorphism produced by a quartz-monzonite intrusion upon Silurian limestone in New South Wales (*Geol. Mag.*, LXVIII, 1931, pp. 289–314). The rocks are divided broadly into marbles, hornfelses, skarns, and hybrid diopside rocks. The first two groups are interpreted as being due to the recrystallisation of limestone containing impurities which have reacted with the lime of the sediments to give lime-silicates and certain other minerals. The skarns are shown to be due to metasomatic replacement of recrystallised limestone by magmatic solutions rich in iron and silica. The hybrid rocks are explained as developing from limited marginal assimilation of limestone by the magma.

Dr. W. Q. Kennedy has described in great detail the monzonitic igneous complex of Traversella (Piedmont, Italy), and the pyrometasomatism to which it has given rise in the adjacent carbonate rocks (*Bull. Suisse Min. Petr.*, XI, 1931, pp. 76–139). A zone of calc-silicate rocks invariably intervenes between the igneous mass and the limestones. These are classified as kata-contact rocks (high temperature) with diopside, garnet, and olivine ; meso-contact rocks (intermediate temperature) with tremolite and hornblende ; and epi-contact rocks (low temperature) composed of hydrous silicates such as talc, chlorite, and serpentine, associated with carbonates. These rocks have been formed by magmatic solutions carrying chiefly silica and ferric iron oxide, which have reacted with the lime and magnesia of the country rocks.

The monzonite intrusions of the Stockton and Fairfield Quadrangles (Utah) have produced notable contact metamorphism in the neighbouring rocks (J. Gilluly, *U.S. Geol. Surv., Prof. Paper* 173, 1932, 171 pp.). Marmorisation and dolomitisation of limestones, and propylitisation of igneous rocks have occurred on a small scale. Silicification, with the production of jasperoid, is widespread, and a large amount of contact silicates such as wollastonite, epidote, garnet, and adularia have been formed. Sulphides have accompanied the jasperoid and silicate phase of metamorphism, and the ore deposits of the region (gold, gold-mercury, silver, silver-lead, zinc, and copper) are due to this phase.

BOTANY. By Prof. E. J. SALISBURY, D.Sc., F.L.S., University College, London.

Ecology.—An interesting account of flower production in the Lemnaceæ is given by L. E. Hicks in the *Ohio Journal of Science* (pp. 115–28, 1932), in which the existing data are collected and

the results of experiments with varying external conditions are described. Treatment with ultra-violet light induced flower-formation in *Lemna minor*, *L. trisulca*, *L. minima*, *L. cyclostasa*, and also *Wolffia columbiana*. Growth of plants on various concentrations of nutrient solutions did not induce flower formation, and negative results were also obtained when the plants were starved. Changing the length of the period of illumination and the intensity of light had no effect apart from stimulation of vegetative activity, whilst the addition of a large variety of chemical substances had no effect in stimulating flower production with the sole exception of sodium hydroxide. The author concludes that the conditions necessary for flower production are well-nourished plants with good food reserves subjected to a sudden check to vegetative activity and adequate illumination.

The occurrence of *Rhododendron maximum* in New Jersey is discussed by E. L. Spencer (*Bull. Torrey Bot. Club*, pp. 410–14, 1932). It occurs in thirty-six stations in soils that range in acidity from *p*H 5·2 to *p*H 2·9 near the surface, and from *p*H 4·8 to *p*H 2·9 at a depth of from six to twelve inches. Low light intensity and high humidity associated with shelter appear to be important factors combining with the soil reaction in determining the distribution.

Recent investigations by Ligon and Pierre (*Soil Science*, vol. XXXIV, pp. 307–17, 1932) indicate that alumina may be toxic in very low concentrations. Using *Zea*, *Sorghum*, and *Hordeum* as experimental material in water cultures, a depression of growth was exhibited when only one part of alumina in a million was present. This depression, as measured by weight, amounted to 25 per cent. in the case of maize, 16 per cent. in the case of sorghum, and 60 per cent. in the case of barley. Cultures with the same hydrogen-ion concentration, but increasing amounts of alumina, exhibited increasing depression of growth. All three species showed a lower yield at *p*H 4·5 than at *p*H 6, but it is noteworthy that the depression due to this increase of acidity was least marked for barley, although this is most sensitive to increase of alumina. The maize, on the other hand, which is most affected by the increase of acidity is far less affected by increase of alumina, which, even at concentrations of ten parts per million, gave a maize yield of 45 per cent., whereas barley, at the same concentration, only yielded 15 per cent.

The almost pure stands of *Pinus palustris*, covering about half the coastal plain from Texas to Virginia, are held by H. H. Chapman to be conditioned and maintained by the frequency of fires (*Ecology*, vol. XIII, pp. 328–34, 1932). This species is completely adapted to resist fire, owing mainly to its deep

tap-root containing large food reserves, its thick bark, and the protection of the terminal bud by the uppermost green leaves. It offers a marked contrast in this respect to the other southern pines and the oaks of the same area. Complete protection of experimental areas from fire shows that suppression of *Pinus palustris* occurs in about fifteen years as the result of the growth of competitors, so that the frequent fires are a necessary condition for the maintenance of these stands of long-leaved pine. Furthermore, the fires have the effect of reducing the attacks of a fungal parasite, *viz. Septoria acicola.*

From a paper by A. Melderis (*Acta. Horti. Bot. Univ. Latviensis*, pp. 123–58, 1932), it appears that the seed development of *Erythræa* depends upon illumination, and that the later in the season that pollination occurs the longer is the period which elapses before the seed is ripe. The period varies from thirty days (pollination in August) to sixty days (pollination in September). *Erythræa centaureum* was found to present races with both round and oval pollen, but that of *E. pulchella*, *E. vulgaris*, and *E. maritimum* was uniformly oval.

Investigations by B. S. Meyer on *Pinus rigida* give no support to the view that increased hardiness to low temperatures is associated with increase in the amount of bound water. The leaves of this species are not frost-resistant in summer, but raising the temperature in winter did not cause a loss of frost-resistance as Winkler found in the evergreens he studied (*Bot. Gaz.*, pp. 297–321, 1932).

A new species of *Microspora*, under the name *M. Ficulinæ*, is described by P. Dangeard, which occurs as a symbiont in the cortex of the maritime sponge *Ficulina ficus*, and is unique in the genus *Microspora* in respect to its marine character (*Bull. Soc. Bot. Fr.*, p. 419, 1932).

From a study by R. Harries on the factors influencing the development of the gametophytes and young sporophytes of *Laminaria* it appears that increase of iodine in the form of potassium iodide accelerates both growth and reproduction, whilst periodic additions of phosphates and nitrates are essential. Light of short wavelength seems also necessary for reproduction (*Ann. Bot.*, pp. 893–928, 1932).

Cytology.—Reproduction in various Swedish and Swiss strains of *Poa alpina* has been studied by Muntzing, and no less than thirteen different chromosome numbers were found. Some of the plants reproduce sexually, others produce seeds apomictically. The apomictic individuals are characterised by the higher and less variable chromosome numbers. The range observed in the two types was from twenty-two to thirty-eight chromosomes. A striking feature was the apparently good pollen of the apomictic individuals and the higher percentage

germination of the seeds which they yielded as compared with the sexually produced seeds, an increased germination amounting to nearly 40 per cent. Both apomictic and sexual types are also recorded for *Poa pratensis*, in which the diploid numbers also show a range from sixty-four to eighty-five. *Poa nemoralis*, which has been recorded as having diploid chromosome numbers of twenty-eight and forty-two, was found with fifty-six chromosomes (*Hereditas. B.*, vol. XVII, pp. 131–54, 1933).

Stebbins (*Bot. Gaz.*, p. 322, 1932) describes the cytology of the parthenogenetic species of *Antennaria*, in which he finds chromosome numbers of from forty-two to eighty-four, as compared with a diploid number of twenty-eight in the species producing seed normally. These results, and those of Muntzing quoted above, confirm the usually higher number of chromosomes in parthenogenetic species generally. Compared with the sexual species of *Antennaria*, the parthenogenetic species have fewer antipodal cells (eight to ten), which suggests that multiple antipodals, in this group at least, are of secondary origin. It is of interest also to note that the parthenogenetic species bloom about three weeks later than the normal species.

Anatomy.—An investigation by M. E. Odell (*Ann. Bot.*, pp. 941–63, 1932) of the epidermal characters of angiospermous leaves indicates that these are unsafe criteria for purposes of identification even when combined with data as to leaf form. Cells of similar shape are met with in quite diverse families, whilst different shapes may occur within the same genus, or even in different leaves of the same species. The characters of the stomata were also found to be too subject to variation to serve as reliable indices of taxonomic affinity, and the authoress concludes that the structure of the epidermis cannot be safely utilised in the identification of fossil angiosperm remains.

An endodermis histologically the same as that of the typical angiosperm root is described by G. Trapp as present in the leaves of *Litorella lacustris* and the leaves of eight species of Plantago. In the first named, in *Plantago coronopus*, *P. major*, and *P. lanceolata*, the endodermis is of the primary type, whereas in *Plantago maritima* and the other species examined the endodermal cells possess a suberin lamella in addition to the casparian strips. The endodermal differentiation was found to be most evident towards the base of the leaf and decreasing upwards. The presence of this endodermis in the leaves is regarded as having no functional significance (*Trans. Roy. Soc. Edin.*, pp. 523–46, 1933).

The anatomy of the carpels of a peloric flower of *Digitalis purpurea* has been investigated by Mrs. Arber, who finds that their structure affords striking evidence in support of the inter-

pretation of the carpel as a leaflike organ bearing marginal ovules (*Ann. Bot.*, pp. 929–39, 1932).

Morphology.—P. H. Mehra, describing peculiarities of the gametophyte of *Adiantum capillus-veneris* (*Current Science*, p. 169, December 1932), records the abnormal presence of an archegonium on the upper surface of the prothallus, and of an instance of three free nuclei, in place of the usual two, in the neck canal. A few instances of embedded antheridia were also observed.

PLANT PHYSIOLOGY. By Prof. WALTER STILES, Sc.D., F.R.S. The University, Birmingham.

Germination and Dormancy of Seeds.—Investigations dealing with the dormancy of the seeds of two species of Compositæ have been described by W. E. Davis. In his first paper (" Primary Dormancy, After-ripening, and the Development of Secondary Dormancy in Embryos of *Ambrosia trifida*," *Amer. Journ. Bot.*, **17**, 58–76, 1930), he points out that fruits of *Ambrosia trifida* at maturity fail to germinate after removal of the seeds from their enclosing envelopes, composed of a thick walled involucre and the pericarp. The dormancy varies not only with the crop and the individual, but also in different parts of the same embryo, being more pronounced in the hypocotyl than in the cotyledons and plumule, which frequently develop while the hypocotyl remains dormant.

The seed is of the type that requires a period of after-ripening for germination to be possible. This after-ripening takes place slowly in ordinary dry storage, but is much more rapid if the seeds are kept on a wet medium such as moist cotton wool at 5° to 10° C. Below a minimum water-content of the seeds after-ripening will not take place at all, as in the case of fruits stored over sulphuric acid. But there is also a close relationship between water-content of the embryo and temperature, for, whereas at low temperatures after-ripening is most rapid in seeds with high water-content, at high temperatures after-ripening does not take place at all in fully saturated seeds. It appears that the after-ripening process requires a low respiratory intensity. During after-ripening there is a slight increase in acidity and a considerable rise in catalase activity. The germination of after-ripened seeds within intact fruits is often prevented if the temperature is too high. This appears to be traceable to the oxygen supply being insufficient for the normal respiratory activity at the high temperature. Exposure to such a condition does not kill the seeds, but these revert to a dormant state; they exhibit, that is, secondary dormancy. The after-ripening of seeds of *Ambrosia trifida* thus seems to be associated with a low rate of respiration, while

secondary dormancy is brought about by restricted respiration at high temperatures caused by low permeability of the seed coverings to oxygen.

In a second paper (" The Development of Dormancy in Seeds of Cocklebur (*Xanthium*)," *Amer. Journ. Bot.*, **17**, 77–87, 1930) the same author deals with the production of dormancy in an allied species. Here the mature seeds, divested of their coverings, show no dormancy, but this can be induced by limiting the exchange of gases between the seeds and the atmosphere by coating the intact seeds with clay or agar-agar. After the seeds have been rendered dormant in this way, storage in a moist atmosphere at a low temperature (*e.g.* 5° C.) led to the removal of the dormant condition. During the period of storage the catalase activity rose, and so did the respiratory activity of the seed. The seeds thus exhibit in many respects a behaviour similar to that shown by *Ambrosia trifida.*

Lela V. Barton has carried out experiments on the acceleration of germination of the seeds of a large number of coniferous species (" Hastening the Germination of some Coniferous Seeds," *Amer. Journ. Bot.*, **17**, 88–115, 1930). The seeds were stratified by mixing them with moist acid peat, and they were then placed to germinate at 0°, 5°, and 10° C., and in some cases at higher temperatures. In some cases weekly alternating temperatures of – 5° and 5° C. and 5° and 10° C. were used. Samples were taken from these seeds at intervals and planted in pans containing equal amounts of sand, peat, and wood soil, and kept in a greenhouse. Generally low-temperature stratification was found to have a favourable effect on the germination of coniferous seeds. Thus the germination of seeds of *Pinus austriaca, P. Banksiana, P. Laricio,* and *P. ponderosa* was greatly speeded up after stratification for two months at 5° C., while a large number of other species showed more rapid germination as a result of this treatment. *Pinus Lambertiana,* however, gave the best results after stratification for three months at 10° C. The alternation of the weekly temperature between – 5° and 5° C. had no accelerating effect on germination of the seeds of a number of *Pinus* species, including *P. excelsa* and *P. Strobus.*

An examination of the cause of dormancy of the seeds of *Melilotus alba* has been made by D. H. Hamly (" Softening of the Seeds of Melilotus alba," *Bot. Gaz.*, **93**, 345–75, 1932). This is a " hard " seed, in which dormancy is related to the impermeability of the seed coat, since without the removal of this, or until it is rendered permeable, the seed is unable to germinate. Hamly has found that the impermeability is due to suberin which is present in the form of caps to the cells of a layer in the seed coat. Separation of these caps from one

another, so that they no longer form a continuous layer, enables the cells within the layer bearing the caps to absorb water and thus effects so-called "softening" of the seeds.

W. J. Robbins and K. F. Petsch have examined the effect of water-content of seeds in relation to the loss of viability by exposure to high temperature ("Moisture Content and High Temperature in Relation to the Germination of Corn and Wheat Grains," *Bot. Gaz.*, **93**, 85–92, 1932). Seeds with different water-content were obtained by drying the seeds over concentrated sulphuric acid, or by soaking them in water at laboratory temperature (about 21° C.). The seeds were then exposed to various temperatures for different lengths of time and then transferred to conditions suitable for germination. From the data so obtained the temperatures required to kill 75 per cent. of the grains at different water-content were found. It was established that with increasing water-content, both of the whole grain or of the embryo only, this temperature becomes lower. The temperature is, however, lower when the moisture-content of the whole grain is considered than when the moisture-content of the embryo only is taken into account. Thus, with Reid's Yellow Dent maize the lethal temperature is 48° when the water-content of the whole grain is 40 per cent., but 58° when the water-content of the embryo alone is 40 per cent. The authors therefore state that any attempt at solving the problem of the relationship between water-content of protoplasm and death temperature must take account of the water-content of the non-living portion of plant material. Since, however, no data are presented with regard to the relative amounts of living and non-living material in the endosperm, the application of the results given is not clear.

A short but interesting paper by H. Kummer deals with the significance of fats and fatty acids in light-sensitive seeds; that is, seeds which germinate with difficulty in the dark. ("Fett und Fettsäuregehalt bei Gramineensamen in Beziehung zur Lichtbedürftigkeit bei der Keimung," *Ber. deut. bot. Ges.*, **50**, 300–3, 1932.) A number of grass seeds were examined and found to possess a high content of fat, varying, in fact, from 4 to 26 per cent. Many of these were found to possess a relatively high percentage of fatty acid, but this varied not only with the species but also with the variety. Those possessing a high proportion of acid germinated readily in the dark, whereas the germination of those with a low acid-content was retarded in the dark. Among seeds of the former type are *Trisetum flavescens*, *Alopecurus pratensis*, *Holcus lanatus*, and *Aira flexuosa*, while to the latter type belong *Koeleria cristata*, *Anthoxanthum odoratum*, *Dactylis glomerata*, *Poa trivialis*, and *P. pratensis*. It may also be significant that other light-sensi-

tive seeds containing fat, such as those of *Nicotiana tabacum*, *Lythrum salicaria*, and *Epilobium roseum*, are also characterised by a low content of fatty acid.

A study on the chemical changes taking place during germination of Soya bean seeds has been made by F. W. Van Ohlen (" A Microchemical Study of Soy Beans during Germination," *Amer. Journ. Bot.*, **18**, 30–49, 1931). The data presented were derived only from microchemical tests, but even so, provided interesting information on a subject about which more knowledge is very desirable. At the outset the cotyledons contain large amounts of protein, fat, and a non-reducing sugar, as well as a little starch. On germination reducing sugar makes its appearance, the amount of starch in the cotyledons increases for the first five days, remains approximately constant in amount for another four days, and then decreases rapidly. In the meantime, after accumulating in particular in the upper part of the hypocotyl during the first three days, it has disappeared from the root, next from the hypocotyl, and then from the epicotyl. The disappearance of the reducing sugar follows about two days after the disappearance of the starch from the respective parts of the seedling. Non-reducing sugar also disappears and could not be detected in hypocotyl, plumule, and cotyledons three, four, and seven days respectively from the commencement of germination.

The fat in the cotyledon begins to disappear at the base, and the disappearance progresses to the apex, the palisade losing its fat more slowly than the rest of the cells.

Asparagine, although not found in cotyledons, plumule, or radicle, appears in the hypocotyl on the third day from the commencement of germination and continues to increase. At the same time there appears to be a gradual conversion of organically bound phosphorus and magnesium to inorganically bound. Although both appear in quantity at the growing points, they also increase in amount in the cotyledons. The potassium appears to move rapidly from the cotyledons. In the meristem of the root tip it was not possible to detect starch, reducing sugar, fat, asparagine, or inorganically bound phosphorus.

The last paper to be mentioned here is by H. T. Darlington (" The Fifty-year Period for Dr. Beal's Seed Viability Experiment," *Amer. Journ. Bot.*, **18**, 262–5, 1931), and deals with the germination of seeds buried in a bottle about fifty years previously (in 1879). The bottle constituted one of a set of twenty buried by W. J. Beal at the same time, eight having been dug up and the viability of the enclosed seeds examined at five-yearly intervals until 1920, the date of the last test previous to that now described. Beal's first list contained

twenty herbaceous species and two trees. The seeds of the two trees (*Quercus rubra* and *Thuja occidentalis*) did not germinate at the end of the first five-year period in 1884; but in the twenty-fifth year seeds of eleven of the twenty herbaceous species germinated. At the end of thirty years seeds of eight or nine species were still viable, and at the end of forty years about the same number of species were found to possess viable seeds, although the two lists of species are not quite the same. Thus *Ambrosia elatior* germinated in 1920 for the first time in the course of the experiment, while *Bursa Bursa-pastoris* no longer did so, whereas it had in all previous trials except one in 1889. In the latest trial in 1930 germination of seeds of only five species was observed, these species being *Brassica nigra*, *Œnothera biennis*, *Polygonatum hydropiper*, *Rumex crispus*, and *Verbascum Blattaria*. For the first time in the history of the experiment seeds of *Lepidium virginicum* failed to germinate, nor did any seedlings appear of *Amarathus retroflexus*, which had only failed to produce seedlings on one previous occasion. There are still eleven of Beal's bottles left buried, so that if tests are made every ten years, this examination of the longevity of seeds can be continued till the year 2040, when the seeds tested will be 160 years old.

AGRICULTURAL PHYSIOLOGY. By ARTHUR WALTON, Ph.D., School of Agriculture, Cambridge.

Artificial Insemination.—Artificial insemination is the term applied to the instrumental deposition of semen within the female genital tract. It was first used by Spallanzani in 1780 to demonstrate that the semen of the male was itself sufficient to invoke the development of the fœtus. Subsequently it has been used both in veterinary and human practice to cure certain forms of sterility. Its use in this country has been confined almost entirely to the mare. In 1907 Ivanoff published a series of important experiments in which he demonstrated that artificial insemination of the mare could yield as high a percentage of offspring as normal matings, that the semen could be kept for a short time at room temperature without losing its potency and that several mares could be inseminated with the semen obtained from a single ejaculation. He extended his experiments on a smaller scale to cattle and sheep. The experiments were sufficiently promising to suggest that artificial insemination might have important practical applications in extending the usefulness of valuable sires by the transport of semen to a distance and the insemination of a larger number of females than could be impregnated normally. It was not until after the War and Revolution that experimentation on an adequate scale to test these possibilities was undertaken. Soviet Russia

was faced with the fundamental reconstruction of a depleted live stock. Government control and collectivised farming made large-scale experimentation possible. In the Breeding Centres established by the Government artificial insemination was first used as a prophylactic measure against dourine, a contagious venereal disease of horses. Mares were impregnated without actual contact with the stud stallions, which were thus kept free from infection (Ivanoff, *Journ. Agric. Sci.*, 1922).

In the meantime a laboratory for research on artificial insemination was established, and has now published a co-operative work with a very full discussion of the whole subject from a scientific standpoint and describing the results of many important experiments. (Kusnezova, Milovanov, Nagaev, Neuman, and Skatkin, *Artificial Insemination of Cattle*, Institute of Animal Breeding, Lenin Agricultural Academy, 1932. *A translation of the more important parts of this work will be published shortly by the Imperial Bureau of Animal Genetics, Edinburgh.*) Methods for the collection of the semen and its injection into the female have been greatly improved, and artificial media for the dilution and preservation of the spermatozoa have been devised. A review of all the results obtained is beyond the scope of this report, but some idea of the magnitude of the experimentation can be gathered from the following figures: In 1928 at one centre 3,972 ewes were inseminated, and produced 62·3 per cent. of lambs as against 87·5 per cent. from normal matings. Poor results in some cases were attributable to inexperience and faulty technique. In the following year 1,078 ewes were inseminated, and the percentage rose to 72·7 as against 76·6 normal. Experiments with cattle were carried out on a similar scale. In one season at fifteen breeding centres, 14,404 cows were inseminated. The calving returns are not given, but the percentage pregnancies based upon the cessation of œstrus is given as 83·7. In some cases more than 1,000 calves were obtained from one bull, and the writers conclude that "at the present moment there is no technical obstacle to prevent 1,200–1,500 calves being sired by a single bull during a 60-day breeding season; the only obstacles which exist are in the matter of organisation." Thus the biological problem of extending the usefulness of the proved sire has apparently been solved in Russia. In this country, owing to the small size of the farms and the lack of centralised control, the organisation of breeding on similar lines might be difficult. There are, however, instances where the impregnation of a much larger number of ewes on one farm by a single male might be advantageous and could now be carried out without much difficulty. For further extension of artificial insemination to cattle and horses on farms and small holdings in

this country, means of transport and preservation will be essential. Methods devised by Hammond and Walton (*Journ. Exp. Biol.*, 7, 1930) proved successful in the preservation of rabbit spermatozoa for upwards of seven days. By adopting similar methods the Russian workers have obtained fertility after storage of bull semen for forty-eight hours. This is but a beginning, but the day may not be far distant when semen from the best sires will be distributed over a wide area, and a very great economy affected by reducing the number of males of poor quality.

The Foundations of Cattle Breeding.—Several scientific papers have been published within the last few years by Prof. Duerst, but the recent appearance of an important volume, *Grundlagen der Rinderzucht* (Berlin, 1931), provides an opportune moment to review his work. The book treats of cattle breeding mainly from the anatomical and physiological aspects. With carefully devised biometric methods a serious effort is made to place what are commonly called " fancy points " on a quantitative basis and to correlate them with physiological functions. The main thesis of the book is the differentiation of two principal types, the " respiratory " type (Atmungstyp) and the " digestive " type (Verdauungstyp). The former is characterised by a relatively greater development of the thorax. It is therefore more adaptable to high altitudes or hot climates, where the oxygen pressure is below normal. The " respiratory " type is relatively catabolic and capable of producing a greater metabolic output, as, for instance, a high yield of milk or a high output of energy in the form of work (draught oxen). The " digestive " type, on the other hand, is relatively anabolic and adapted to the storage of body materials. It is the typical " beef " animal of the maritime countries. Prof. Duerst also correlates thyroid activity with production. The " respiratory " type tends to be hyper- and the " digestive " type hypothyroid. Cattle of the Channel Islands show an interesting combination of respiratory type with hypo-thyroidism, which finds its expression in a high fat content in the milk. A short review can hardly do justice to the large amount of evidence which is brought to bear out the main conclusions. As in many statistical studies there is often some doubt as to the biological validity of the argument and the statistical significance of the correlations, even a high correlation may be spurious when the material is genetically diverse. Although during recent times genetical aspects of breeding have perhaps tended to swamp the anatomical and physiological, it is a pity that in this book the reverse process has taken place, and genetical theory is hardly mentioned even in the discussion of coat colour or hereditary malformations.

Effect of Light on Seasonal Sexual Activity.—Seasonal variation in sexual activity is a phenomenon which has interested scientists from classic times and is of very great importance in agriculture. For example, seasonal variation in the number of eggs laid by poultry, or in the milk yield of cows, occasions an instability of price detrimental alike to producer and consumer. Temperature and nutrition have been regarded as the principal agents concerned in determining seasonal variation, but recent work suggests that light may be one of the most important factors. This might have been suspected from experiments on poultry, since it has long been known that artificial illumination increases egg production of hens during the winter months and reduces seasonal variation. The effect has, however, been attributed to the greater uptake of food which accompanies the increased egg production. This explanation was also offered by Rowan (*Proc. Boston Soc. Nat. Hist.*, **39**, 1929) to account for sexual precocity artificially induced by artificial light on *Juncus hyemalis*. Bissonnette, however, in a series of papers (*Amer. J. Anat.*, **45**, 1930; *J. Exp. Zool.*, **58**, 1931; *Phys. Zool.*, **4**, 1931, **5**, 1932) has conclusively shown that the direct stimulus of light is primarily concerned. Subsequently Bissonnette (*Proc. Roy. Soc., B.*, **110**, 1932) and Baker (*Proc. Roy. Soc., B.*, **110**, 1932) have independently shown that light conditions sexual activity in the ferret and vole respectively, thus extending the results to mammals. The nature of the stimulus and the mechanism by which gonadic activity is aroused are yet obscure, but the suggestion of Hogben (*Nature*, **128**, 1931) and Bissonnette, that light stimulates the pituitary and hence indirectly the gonad, appears most feasible.

ARCHÆOLOGY. By E. N. Fallaize.

British Association at York. Archæological Problems and Relations.—Archæologists found much to interest them among the communications which were presented to the anthropological section when the British Association met at York in September last. The address of the Sectional President, Dr. D. Randall-MacIver, "On the Place of Archæology as a Science and some Practical Problems in its Development," had a statesmanlike breadth of view, and raised a number of issues, practical and theoretical, upon which as a practical excavator, as well as a theorist, he was fully qualified to pronounce. These points archæologists will do well to keep in mind as occasion arises. Such matters as the training of an archæologist, museum display, the necessity for early publication of the results of excavation, and the sale of museum duplicates to provide funds for future research were discussed side by side with broader questions, such as the

preservation of archæological sites from the depredations of the untrained observer and those whose object is commercial exploitation. In his view of the urgent necessity for some measure of control of excavation all archæologists in the true sense of the term will entirely concur, though the question bristles with difficulties. Many will also endorse his suggestion that in future excavation part of each site should be set aside for study by future generations in the light of later developments of knowledge and technique, a policy of which the wisdom has been illustrated by recent discoveries at Pompeii. As his own contribution to a scheme of training for the archæologist, Dr. Randall-MacIver offered the suggestion of a period of practice in some craft, such as pottery-making. On the theoretical side the relation between archæology and cognate sciences was outlined. Archæology in the field, he pointed out, provides the bare facts, anthropology gives the colour and the meaning, geology provides a relative, and history or prehistory an absolute time-scale, the latter now beginning about 3300 B.C., geography indicates where the evolution of man and his cultures could have taken place, having in view climatological and geographical conditions at different epochs, and so forth; while in the study of culture, Dr. Randall-MacIver laid down the canons which, in his opinion, should be observed in discussing independent origins and the diffusion of cultural elements.

Ice-Age Man in Britain.—The question of a border-line area in the relation of geology and archæology was also raised in another of the presidential addresses. Prof. P. H. G. Boswell, as President of Section C (Geology), took as his subject "The Contacts of Geology and the Ice Age and Early Man in Britain." More than half his address was devoted to a review of the evidence relating to the Ice Age in Great Britain, which, he pointed out, as a marginal area of glaciation, was particularly favourably situated for stratigraphic observation. After a survey in rotation of the areas in Britain in which traces of human occupation on or beyond the area of glaciation had been observed, he suggested that there were four, if not five, successive glaciations with four interglacial periods, and that early man was established in Britain when it was still a north-western promontory of Europe, and preceded the first glacial period by long ages during which he passed through successive stages as a tool-making animal to arrive at length at the form and technique of a fully developed Chellean implement.

The Mesolithic Age in Britain.—Man in Britain during the last glaciation and the immediately succeeding period was the subject of a group of papers, opening with an account by Mr. A. L. Armstrong of recent excavations in North Lincolnshire,

which had brought to light heavily rolled late Aurignacian implements on a site at Hardwick Hill, east of the River Trent. These suggested the existence of palæolithic man there on the shores of an estuary or glacial lake before the last glaciation. It would appear that a band of hunters had penetrated the Trent swamp and had taken up their residence on the dry uplands of the cliff range and probably the Wold also. Here they had remained through the last glacial events until the coming of the Azilian and Tardenois cultures, which, eventually, had dominated Lincolnshire, as was shown by a number of stratified living-sites in the area. Evidence pointing in the same direction was adduced from a developed Aurignacian (Creswellian) site, discovered by Mrs. E. H. Rudkin on the western escarpment of the Lincolnshire cliff above Willoughton, and from Sheffield Hill, near Scunthorpe, which yielded evidence of the first phase of the developed Aurignacian with superimposed early Tardenoisian. Risby Warren, Scunthorpe, which was also described, exhibits a stratified sequence from Creswellian to earliest neolithic, full neolithic and bronze age. Tardenois is represented by several horizons and can be classified broadly as early and late. For the Tardenois culture, which is here so fully represented, Risby Warren may be considered the type station in England.

On a broader basis, Mr. J. G. D. Clark reviewed the evidence relating to the Mesolithic Age in Britain as a whole. Knowledge of this period has reached a stage in which distinctions of typology and chronology are now possible. The results of Mr. Clark's studies of this phase of culture are set forth more fully in his recently published *The Mesolithic Age in Britain* (Cambridge University Press), in which it is stated broadly that while the Upper Palæolithic in Britain already showed certain mesolithic tendencies, Tardenois was definitely an intrusive culture in both the early and middle periods, and possibly continental influences are also to be discerned in the late period. Mr. Clark divides the whole country into two areas. Area A is characterised by the development of Tardenoisian and the tranchet axe is rare. In Area B, the south-east of England, the tranchet is common, but the late Tardenoisian is almost absent, its place being taken by microlithic points of a non-geometric type. Reference must also be made here to Mr. F. Buckley's useful paper on the mesolithic artefacts of the Pennine Chain which seem to point to two distinct races of Tardenois folk, one the people of the " Narrow Blade " industry and the other the people of the " Broad Blade." The former made numerous small geometric tools and used open encampments; the latter made few geometric tools, but many pointed blades, and erected huts or wigwams on their camping

sites. The micro-graver is common to both. As a whole the discussion at York not only indicated a keen interest in what has been rather a neglected period of prehistory; but it also has served to clear the ground for future lines of enquiry.

Flint-mining.—Mr. Clark's book to which reference has been made contains a number of valuable appendices dealing with special points connected with the mesolithic age, and one which discusses the evidence relating to the flint-mining industry in which Mr. Armstrong's interpretation of the evidence of early flint-mining in Britain is discussed. In this connection also may be mentioned a valuable contribution to the study of a much-debated subject by Mr. J. H. Pull, whose recently published *Flint Miners of Blackpatch* (Williams and Norgate) is a detailed account of the mining-shafts, burial-mounds and habitation-sites of a flint-mining settlement in Sussex upon the excavation of which he has been engaged for some years.

Early Mining in Greece.—Communications at York on later periods of British prehistory—several describing excavations in the north of England—must be passed over here to admit of mention of three important papers which dealt with recent work in the Mediterranean and the East. Of these that by Mr. Oliver Davies on "Mining in Greece in Pre-Classical Times" was new both in subject and in technique. It was based on the examination of a large number of ancient mine-workings in Greece and the Aegean, from which, as Prof. J. L. Myres put it in the subsequent discussion, "it seemed clear that throughout antiquity people were much less exclusively dependent upon a few large, rich and fully exploited centres than had been thought hitherto, and that a good deal was to be allowed in their acquisitions for those numerous, scattered, short-lived, but nevertheless in some instances very early, sources of the principal metals." Mr. Davies brought together passages in early literature relating to gold, silver, copper, and other metals, and gave the results of his search for the sources from which they had been obtained. It is to be noted that, contrary to the generally accepted opinion, he found a lack of evidence to support the early mining of copper in Cyprus. He also suggested that the rarity of gold in Greece in the early Iron Age, evident in Homer, and also to be inferred from the amazement of the Greeks at the wealth of Crœsus, may have been due to the fact that early accumulations of gold became the booty of pirates and raiders, while Aegean gold might have gone to Solomon in Palestine and to Midas in Phrygia. An extended abstract of Mr. Davies's paper is to appear in *Nature*, and the evidence for mining activity in prehistoric Macedonia will be found in the *Journal of the R. Anthropological Institute*, vol. LXII, 1932, pt. 1.

Samaria.—A second paper of considerable interest was the

account by Prof. J. W. Crowfoot of the resumed excavation of Samaria, the site on which the Harvard Expedition suspended operations in 1910. The principal results of the present joint expedition of Harvard University, the Palestine Exploration Fund and other bodies, which began work in 1931, have been the uncovering of a magnificent section of the outer of the two defensive walls of the Israelite period, and the partial determination of the plan of the second, the upper, or Palace, wall, a rectangle enclosing an area of eight acres. Ivory plaques, decorated with *motifs* from various fields, Egypt, Assyria, Anatolia, and the like, which had ornamented articles of furniture, bore witness to the luxury and wealth of Samaria denounced by the Hebrew prophets.

Nineveh.—No less interesting, whilst of broader significance, was Mr. M. E. L. Mallowan's account of the prehistoric civilisations of Nineveh as brought to light by the British Museum's excavations in 1931–2 under the direction of Dr. Campbell-Thompson. Excavation has shown that four-fifths of the contents of the mound are pre-Assyrian. A series of civilisations ending at about 3000 B.C. has been revealed. The latest is a protohistoric culture which shows close relation with the civilisation of Ur. The mound was dug to a depth of 92 feet to virgin soil, and five distinct prehistoric cultures were revealed, of which the earliest, characterised by a coarse plain and incised ware, cannot be placed much later than 5000 B.C. Belonging to the second is a ware with brilliant three-colour decoration on a burnished slip, showing affinities with the early ware of Carchemish and Tell Halaf, though the latter is probably a late stage and is not found at Nineveh. The third phase has infant urn-burial, grey burnished pottery, seal impressions with animal drawings, and early examples of metal. In the fourth is Erech red ware and seal impressions of the Jemdet Naṣr period, *c.* 4000; while in the fifth, the latest period, appear wheel-made painted pottery, incised pottery, and Sumerian seal impressions. The evidence of sondage is such as to leave time relations and correlations with other cities beyond question.

Recent Excavations in Britain. East Anglia and Guernsey.—Preliminary reports on excavations in the field in progress in Great Britain during the past season indicate considerable activity and sound work, if without any discovery of outstanding sensational interest—a state of affairs for which the excavators themselves are perhaps not entirely unthankful, as it has entailed fewer interruptions to their work. Among operations with a more or less definitely circumscribed objective may be mentioned the work of Mr. J. Reid Moir on the early stone industries of East Anglia, which has been undertaken with the financial assistance of Sir Henry

Wellcome, and of which the results will no doubt be displayed in due course in the galleries of the new Wellcome Museum, and the investigation of the dolmen of Déhus in Guernsey by Miss V. G. C. Collum under the auspices of the British Museum and with the financial assistance of Sir Robert Mond. Mr. Reid Moir reports important finds of early Chellean implements of various types from the Cromer Forest Bed. Miss Collum has already discovered the foundations of the ramp by which the stones of the Déhus monument were placed in position, and has made some corrections of the accepted plan. She hopes that in due course her investigations in the island may throw light on the date of its megalithic monuments.

Verulamium.—Among major operations, Verulamium naturally takes first place at the moment. The most striking discovery of the season was that of another large mosaic Roman pavement in the western wing of the important second-century house in which the " Neptune " pavement was discovered last year. Some interesting particulars of the history of this house were obtained. It occupies a space of about 100 feet by 70 feet at the centre of the city, and, apparently, was rebuilt in the third century, when part of the old building was incorporated in the new, the elaborate heating system of the earlier structure, however, being cut off. The room in which the second recently discovered mosaic was found had an elaborately painted plaster wall, which had collapsed as if pushed down. A further discovery was that of the western gate, by which the road issued to Silchester. It was found to be smaller than the previously discovered north and south gates. It had two square flanking towers and a triple arch over a road 30 feet wide with two side paths. The circuit of the first-century defences, which preceded the city wall, is being traced, and a defensive ditch of this system has been opened up.

Colchester.—At Colchester the search for the headquarters of the British chieftain, the " Palace of Cymbeline," was continued without success. Excavation proceeded on the part of the British site discovered in the previous season. It produced some interesting relics, notably a large bronze cauldron, but proved to be an area of British dwelling-sites rather in the nature of " kraals." It was occupied by the troops of Claudius in the operations of A.D. 43 when a camp of unusual form was made over the original British dwelling-sites. This area is now shown to have been under five distinct occupations. After the Claudian operations it was used as something in the nature of a depot for material while the neighbouring Roman town was in course of erection. This was followed by some rather squalid British dwellings, which were destroyed by fire presumably by Boudicca when she attacked Camulodunum in A.D. 61 ; and

it was then once more occupied, but only temporarily, by Roman troops, possibly by those who were engaged in the pursuit of the queen.

Meare Lake Village.—At Meare, near Glastonbury, excavations on the lake-village have been resumed by the Somerset Archæological Society under the direction of Mr. H. St. George Gray and Dr. Arthur Bulleid after an interval of two years. Operations have now begun on the western half of the village, of which the eastern edge is being examined. The western half of the village was separated from the eastern by a waterway of about a hundred yards' width, apparently without a causeway. A large wooden substructure of massive beams was uncovered. Upon this clay was placed to form the floors of the houses. Among the smaller finds were a large quantity of bronze in the form of sheet, "drops," slag, rings, rivets, and scabbard bordering, armlets of Kimmeridge shale, sheet lead, showing nail-holes at the edges, and beads, including egg-shaped beads in clear glass of a type not previously found in Somersetshire lake villages. A human skull, apparently of a young adult male, was the first human skull to be found at Meare.

The Viking Age in Ireland.—An excavation which has proved most striking in its results has been carried out by an Archæological Expedition of Harvard University at work on a crannog at Ballinderry, near Moate, co. Westmeath, in Ireland. The crannog is of Viking age, dating at about 1000 B.C., and was first identified four years ago through the discovery of a fine example of a Viking sword in the course of the clearing of a drain. The island is constructed of layers of brushwood and peat with a substructure of beams carrying further layers of brushwood and peat upon which a circular house was erected. At a later date further layers of peat were placed on its ruins, and on this two rectangular houses were built. The inhabitants were at once hunters, herders of cattle and agriculturists, as is shown by the animal bones and by the relics of their material culture, which include the coulter of a plough and stone querns for grinding corn. Apparently they had no pottery, but used wooden utensils. Well-made barrel staves and well-turned wooden vessels were found. The settlement was evidently one of some wealth and refinement, for among the finds were not only a Viking battle-axe and a fine example of the bill-hook, knives, axes of iron, etc., and a wooden bow, but there were a quantity of bronze pins, a tenth-century gilded pin, a silver kite-shaped brooch, a beautiful hanging bowl of bronze, described as the finest bronze ever discovered in Ireland, and a holed gaming board of wood elaborately patterned and ornamented, which is said to be the finest Viking object hitherto

found in Ireland. The decorative patterns suggest a North British or Manx origin.

The Ballinderry hanging-bowl calls for further notice in view of an interesting discussion on the the hanging-bowls of earlier date, usually known as the "Saxon bowls," which has arisen recently. The Ballinderry bowl is a pointed oval, 9¼ inches long, 7 inches wide, and about 2¼ inches deep. It has three animal heads for suspension, and the base is ornamented by an elaborate engraved rosette pattern. Underneath the pointed end is a plaque on which is an acanthus scroll of about A.D. 1000. It is suggested that this bowl descends from the Romano-British and Anglo-Saxon hanging-bowls.

Celtic Art.—Now in regard to the earlier or "Saxon" hanging-bowls, a revolutionary theory was put forward by Mr. T. D. Kendrick in *Antiquity* for June last, in which he argues, on the basis of a detailed analysis of the decorative "Celtic" ornament of these bowls, and more particularly of the escutcheons, that they are entirely Romano-British or British in origin and not Saxon, the series coming to an end about A.D. 600, and thus requiring a much earlier dating than is usually allocated to them. Further he suggests that the end of the hiatus in Celtic art during the last part of the Roman period was due not to a renaissance of an ancient Celtic art, but to the adoption and assimilation by Celtic artists of late Roman patterns and *motifs*. On this view the part played by Ireland in the revival of Celtic art becomes a small one, and he holds that it was only after the Saxons had crushed out Celtic art that it found a home for its further development from the seventh century onward in Ireland. The challenge issued by Mr. Kendrick is taken up by Dr. R. E. Mortimer Wheeler in *Antiquity* for September. Here, passing over the objection that no dated example of the hanging-bowl is as early as Romano-British, he argues that some special explanation must be sought for the phenomenon, unique in the history of art, that the two phases of Celtic art, linked by an essentially similar informing spirit, are separated by a hiatus of three centuries of time. Examining Celtic art as a whole in relation to the conditions in which it was produced, he suggests that the Celtic artistic temperament was a plant of tender growth which flourished only in conditions of security and when not subject to commercial competition. Thus it flourished when economic security was thrust upon the Celtic world in Britain by the semi-Teutonic Belgic princes and the might of Rome; but it failed before the mass-craftsmanship of Rome, to revive when the Saxon occupation again brought peace and some leisure to the Celtic population, thus explaining the fact that the hanging-bowl when found in association, such as in a burial,

is invariably with Saxon remains. The unrest on the British frontiers was allayed by the Celtic Church, which offered the native artist a greater degree of congenial patronage, and thus caused the shift of artistic interest from Saxon England to the Irish Celtic Church.

The East—Ras Shamra.—The lull which normally each season precedes resumption of archæological activity in the East has this year been interrupted by the visit of M. Schaeffer to lecture before the University of London and the Society for the Promotion of Hellenic Studies on the French excavations in Syria and the finds in the necropolis of Minet el-Beida. He made the interesting suggestion that in the great beehive tombs of the Ras Shamra area, which have been found filled with objects from Cyprus, Rhodes and Mycenæan Greece, are to be seen the resting-places of important personages of Greek, Cyprio-Greek and Creto-Greek origin. Thus Aegean colonisation on the Syrian coastal belt, which has legendary support, is added to the sources of the racial elements which met in this cosmopolitan gathering-place of the ancient world.

The Indus Valley.—Until the records which have been, and continue to be, discovered at Ras Shamra have been subjected to careful study by expert philologists it is impossible to forecast what light may or may not be thrown on the languages of the proto-historic East by evidence from this evidently polyglot centre. Although it is a far cry from this early civilisation of the Syrian coast to the Indus Valley and its prehistoric culture, both in time and space, yet evidence of the connection of the latter with the nearer East is accumulating. Mr. Ernest MacKay has pointed out (*Times*, August 28, 1932) not only that the seal from Tell Asmar recently found by Dr. H. Frankfort is undoubtedly of Indian workmanship, the *gharial* or fish-eating crocodile and other animals represented on it being repeatedly found on Mohenjo-daro seals and sealings, but that a fragment of steatite vase found at Mohenjo-daro bears exactly the same intricate and unusual pattern as is borne by a double vase of steatite from Susa II. Its Elamite origin is confirmed by the fact that it is of greenish-grey steatite, the only piece of its kind found at Mohenjo-daro. The Mohenjo-daro fragment lay at a depth of 28 feet below datum, whereas Dr. Frankfort's seal, dated round about 2500 B.C., can only be correlated with the upper levels.

Following on Prof. Petrie's suggested interpretation of the figures of the Indus valley sealings, Sir Denison Ross calls attention (*Times*, September 21, 1932) to a communication made to the Académie des Inscriptions et Belles Lettres, Paris, by M. Paul Pelliot, who referred to the discovery by M. Guillaume Hevesy of a marked resemblance between the Indus

Valley script and the pictographs of the well-known Easter Island inscriptions on wooden tablets. The resemblances are certainly striking, but are hardly adequate to carry conviction of any relationship, especially after the essay in the interpretation of the tablets recently made by a committee of the Royal Anthropological Institute. The lack of a connecting link when what must be an enormous gap in time has to be bridged is seriously felt, even though it has been pointed out that the carved wooden figures of the Kafirs of Afghanistan are very like the carved figures of Easter Island.

Peking Man Skeletal Remains.—Among the more interesting of recent publications is the *Bulletin of the Geological Society of China*, vol. XI, pt. 4, which contains the report of Dr. Davidson Black on the skeletal remains of Peking man, other than skull parts, found in the cave of Choukoutien, and a supplementary report by P. Teilhard de Chardin and Dr. W. C. Pei on the stone implements found in the cave. As previously stated, the skeletal remains were recovered at different times over a period of four years from 1928 onward, mainly from material removed from the cave for examination in the laboratory at Peking; but no announcement had been made in the hope of obtaining further material for a fuller description. The bones now described are a left semilunar bone of the wrist, a left clavicle and several terminal phalanges. The semilunar bone supports the evidence of the stone implements that the hands of Peking man were as our own, and differs in no essential particular from that of modern man; while the clavicle, though imperfect, can be estimated to be virtually identical in size and character with a clavicle of similar robustness in a North China adult male. The phalanges, however, are in certain respects abnormal, and though immediately on the discovery of the first example Dr. Black diagnosed it as that of a hominid, a view endorsed by submission to a palæontological expert, the late Prof. W. Mathew, it is like that of no other known hominid. It is evident that the feet of Peking man must have been strikingly different from those of modern man.

Stone Implements from Choukoutien.—The report on the stone implements is interesting because, as the authors state, it is necessitated not only by further field work, but also by a change in the character of the archæological problem involved. It can no longer be argued as to whether these specimens are of human origin. Indeed, in view of the circumstances of the discovery that question could hardly have been seriously in doubt; but it is now under discussion whether they were the work of Peking man, or of another, and presumably more advanced, later occupant of the cave. The authors in this report therefore confine their attention almost exclusively to the implements

from the lowest of the three zones into which the deposits are classified, for it is in this zone that implements have been found *in situ* and in immediate association with the skeletal remains of Peking man. It may be noted, however, that in the uppermost zone, in which numbers of artefacts and burnt bones have been found, the deposits are said to resemble strikingly the classical deposits of the European palæolithic caves. The implements described are classified into roughly chipped blocks, choppers, pointed implements, scrapers and, possibly, anvils. The material is sandstone, veined quartz, quartzite and quartz-porphyric rock, sandstone predominating. The sandstone and quartz were presumably obtained from a neighbouring river-bed. An abundant and characteristic fauna includes *Equus Sanmeniensis*, *Elephas namadicus*, *Rhinoceros Sinensis*, *R* (?) *Tichorhinus*, etc. A comparison with other sites in China, geologically and palæontologically, fixes the place of Choukoutien in the series and definitely assigns it to the early pleistocene; but precise correlation with European series is not yet possible. The authors' provisional conclusion is that the industry is distinctly, but moderately, in advance of what the most primitive recognisable human industry might be expected to be.

South Africa. A Neanderthaloid Skull.—Another discovery relating to early man is announced from South Africa, where Prof. Dreyer has found a human skull at Florisbad Hot Springs, twenty-five miles north of Bloemfontein. It was associated with stone implements which have been submitted to Mr. van Riet Lowe for expert examination. Prof. Dreyer, who has named the skull *Homo Helmei*, in honour of Capt. Helme, the promoter of his research, regards it as a local differentiation of *Homo Neanderthalensis*. In view of the position and character of Rhodesian man, this discovery may have far-reaching effect on the theory of the development and diffusion of human types in South Africa.

Dental Mutilation.—In view of the reference to the mutilation of the teeth in the last issue of SCIENCE PROGRESS (p. 251), attention must be called to a letter from Prof. Elliot Smith which appears in *Nature* of September 3. He there withdraws his statements with regard to the evidential value of dental mutilation in chronology in view of the fact that he had overlooked evidence from other places, which indicates that dental mutilation may be very much more ancient than the Nubian record suggests. He refers to evidence from neolithic remains from North Lancashire and North Wales, the Egyptian Middle Kingdom, a late predynastic skull, and from the so-called stone-age Aino remains from the shell mounds of Japan, of which the last-named had been examined by himself when in

Japan. Though Prof. Elliot Smith regards none of the evidence as conclusive, he thinks the cumulative effect raises the possibility that the practice is much older than he had thought.

New Periodical.—A new archæological publication has appeared in Paris under the title *Préhistoire.* It is edited by Dr. Raymond Lantier with the assistance of an international committee, of which Count Begouen, the Abbé Breuil, Prof. H. Obermaier, Prof. Bosch-Gimpera, and Mr. Miles Burkitt are members. The new periodical has set itself the ambitious programme, in present conditions, of affording a place of publication for articles and monograms which, by their length or their need of illustration, find it difficult to secure acceptance elsewhere. The first number—which in the character of its plates and illustrations in the text should fulfil the promoters' aspiration—contains contributions from Dr. Henri Martin, who describes fully for the first time the remarkable rock-shelter at Roc, Charente, with its Solutrean "art-gallery"; from Prof. H. Obermaier, who describes the late Magdalenian art of the Gotte du "Pendo," near Santander; and from Dr. R. Forrer, who deals with the cult-chariot of prehistory and its survivals in historic times, incidentally working out a theory of the origin of the wheeled cart in bronze-age sun-worship.

ARTICLES

SUPERCONDUCTIVITY

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Introduction

In 1911 Kamerlingh Onnes discovered [1] that at the boiling-point of liquid helium (T = 4·2° K.) the electric resistance of a mercury wire suddenly becomes immeasurably small. This phenomenon, the sudden disappearance of the electric resistance at a given temperature, is called superconductivity.

This great discovery was made in connection with the determination of electric resistance as a function of temperature at low temperatures. At first it was thought (Lord Kelvin and Koenigsberger) that the electric resistance of a pure metal would become infinite at the absolute zero in consequence of the assumption that the electrons, which are the actual conductors in a metal, would then be "frozen." But investigations with Pt, Ag, Au, Hg, at liquid-hydrogen temperatures (13°–20° Kelvin) showed, that if it was permitted to extrapolate the resistance curve towards T = 0° we must not expect an infinitely large resistance, but a resistance equal to zero. Further investigations with Hg at still lower temperatures—those of liquid helium (1°–4·2° Kelvin)—showed, as stated above, that whilst the resistance decreased still a very little above 4·2°, it vanished all at once at this temperature in a small temperature interval (Fig. 1).

Since this discovery, a great number of superconductors have been discovered, not only among the pure elements, but also among the alloys and compounds. They all have the property that the transition point (the temperature at which the resistance suddenly disappears) is very low, generally below 10° K., so that the phenomenon can only be investigated in low-temperature laboratories, *i.e.* at Leiden, Berlin, Toronto, and Washington (Bureau of Standards).

The measurements are common resistance measurements with direct current: the same current flows through the unknown

resistance and a standard resistance. With a Wolff-Diesselhorst compensation apparatus we measure the potential difference between the ends of each resistance; the ratio of these potential differences is equal to the ratio of the unknown resistance and the standard resistance.

There is at present no theory which can explain the different phenomena of superconductivity in a satisfactory manner.

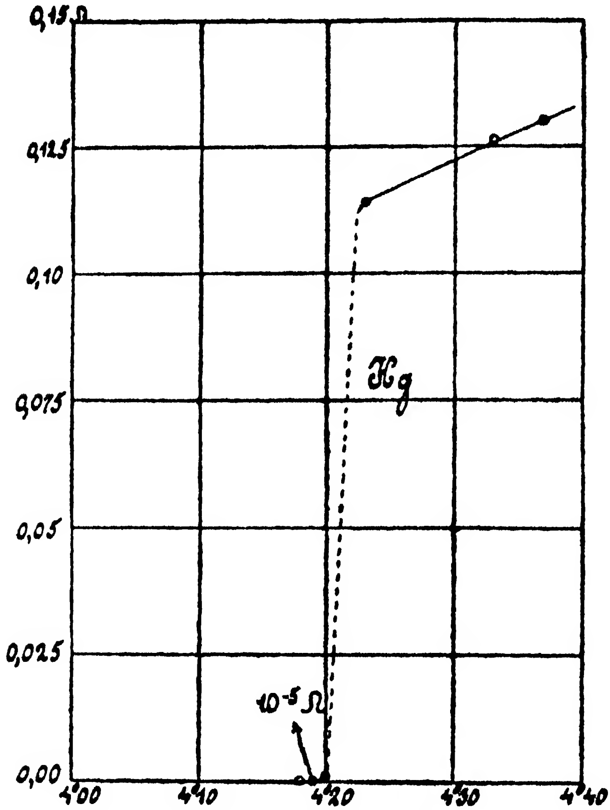

FIG. 1.

We shall give, therefore, in the next pages only a summary of the different experimental results and not of the theoretical attempts to explain them. The summary consists of three parts:

Section I: The superconductivity of elements.
Section II: The superconductivity of alloys.
Section III: The relation between superconductivity and other physical properties.

Section I: The Superconductivity of Elements

§ 1. At present we know altogether ten elements which become superconductive at low temperatures:

Element.	Trans. pt.	Crystal lattice.
Hg	4·22° K.	Rhombohedric.
Sn	3·71° K.	Tetragonal.
Pb	7·2° K.	Cubic, face centred.
Tl	2·37° K.	Hexagonal, close packing.
In	3·37° K.	Tetragonal.
Ga	1·05° K.	Tetragonal.
Ta	4·4° K.	Cubic, space centred.
Th	1·5° K.	Cubic, plane centred.
Nb	8·2° K.	Cubic, space centred.

McLennan found that ruthenium also becomes superconductive, but Meissner's measurements failed to confirm his result, so that we shall omit this element.

The resistance curve of all the superconductors shows the same character. The resistance diminishes over the whole temperature interval, above the transition point the diminution is very slight, but at this point the resistance vanishes entirely in a very small interval (Fig. 1). The resistance curve in the neighbourhood of the transition point is called the *thermal transition curve* and the resistance just above the transition temperature is called the *residual resistance* at this temperature.

When the temperature of a superconductive metal is raised, the resistance-temperature curve is unaltered. From this we draw the conclusion that the thermal transition curve is reproducible, without any hysteresis.

Since the resistance disappears in a small temperature interval, the transition point is not quite definite. Therefore we will define it as the temperature at that point of the transition curve where half the resistance has vanished.

At first, when only the first five elements of the above-mentioned table had been discovered, it was thought that a relation between superconductivity and the periodic system of the elements existed, because these elements have a special place in this system. The other elements, however, do not agree at all with this idea and this hypothesis has now been abandoned.

§ 2. It is possible to destroy the superconductive state of a resistance by the application of an external magnetic field of sufficient intensity [2]. The curve, which represents the change of the resistance with the intensity of the magnetic field (*magnetic transition curve* at a given temperature), is closely analogous to the thermal transition curve (Fig. 2). The field strength required to give the metal half of its residual resistance

is known as the magnetic threshold value at the given temperature. The magnetic threshold value moves from zero at the transitional temperature towards higher field strengths at lower

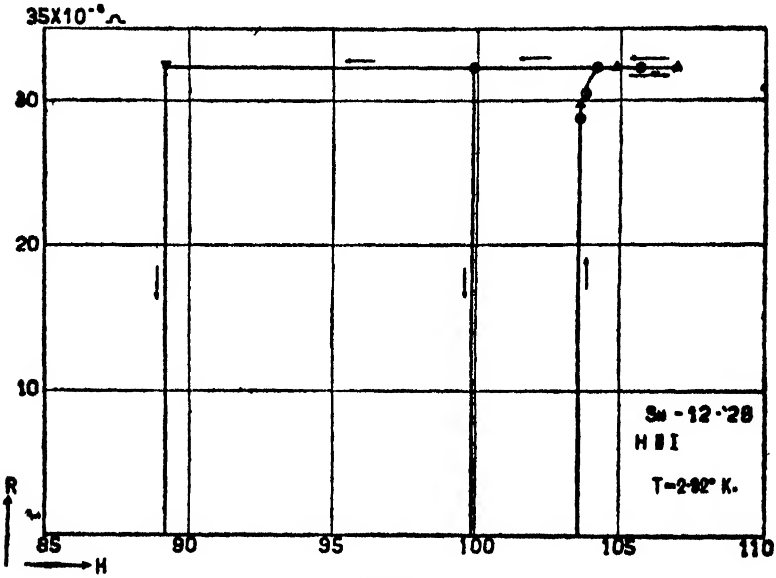

Fig. 2.

temperatures. Figs. 2 and 3 show that the magnetic threshold value is also dependent on the direction of the magnetic field

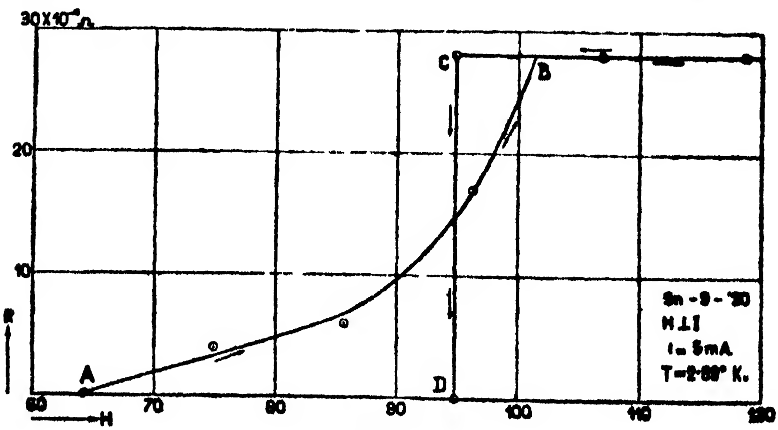

Fig. 3.

relative to the electric current through the wire. Unlike the temperature transition curve, the magnetic transition curve shows a hysteresis effect: the curves obtained with increasing

and with decreasing fields are different. The magnetic transition curve of a Sn single crystal, for example, has the following character (Fig. 2): At a given value of the magnetic field the resistance comes back. When it is restored to its normal residual value, a further increase of the field does not change it any more. In a decreasing field the resistance keeps its normal residual value, even in fields lower than those in which

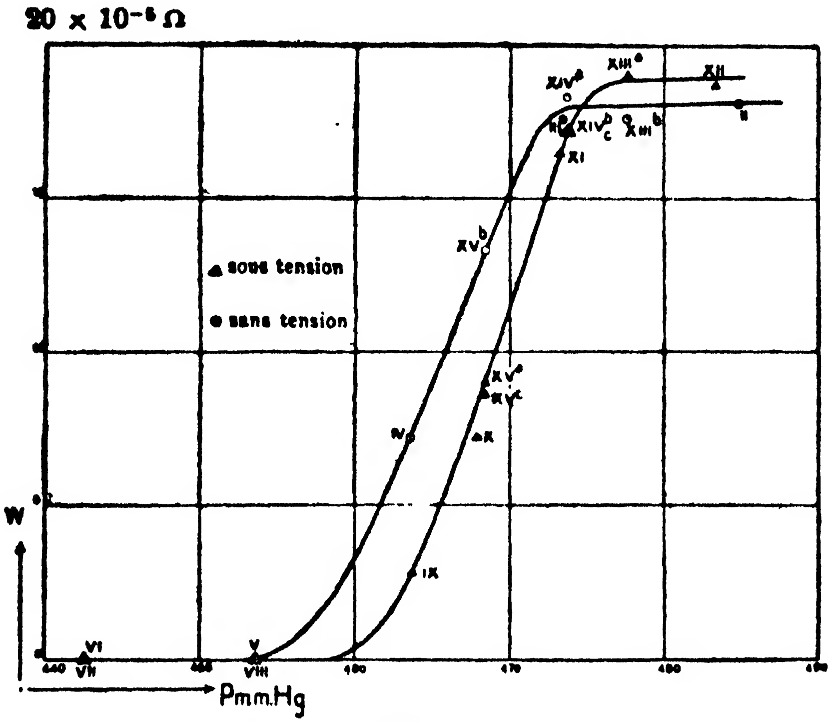

FIG. 4.

it was smaller than the residual value for increasing fields, until it vanishes discontinuously in one step.

The resistance always returns at the same field intensities; its disappearance, however, does not take place at the same intensities of the magnetic field—it is also unreproducible.

By disturbing the superconductivity it is possible to continue the ordinary resistance curve temperatures below the transition temperature. The residual resistances obtained by the disturbance of the superconductive state lie on continuation of the resistance curve for temperatures above the transition point.

Kamerlingh Onnes showed that the superconductivity also disappears when the intensity of the electric current through

the resistance exceeds a critical value [3]. Just as in the case of the magnetic disturbance, there is for every temperature a critical value of the current; when this is exceeded the superconductivity is disturbed. This fact shows that if we measure

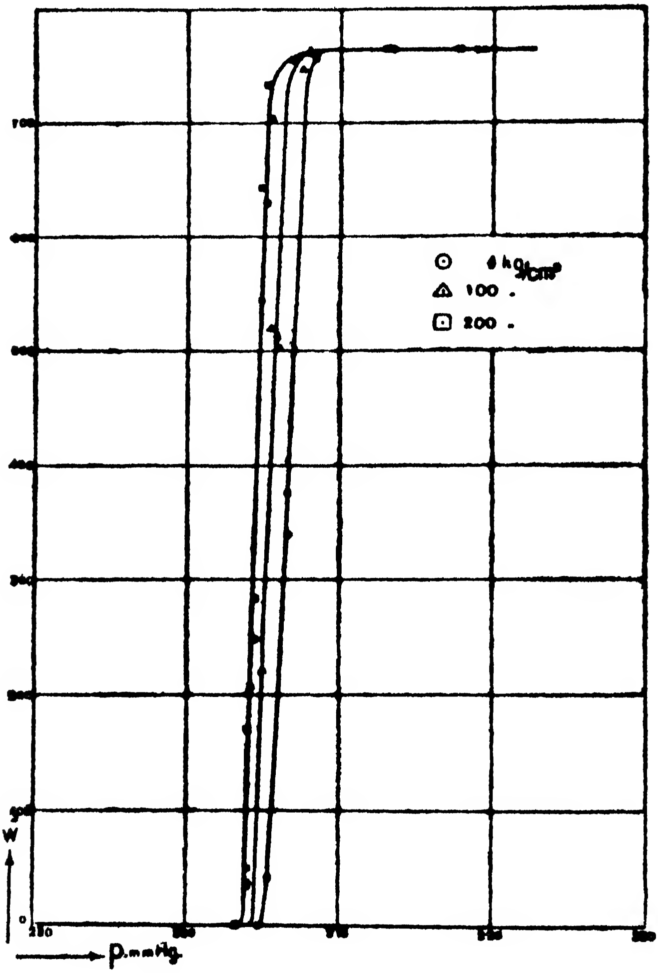

FIG. 5.

a point of the thermal transition curve, the measured resistance is dependent on the current. Ohm's law loses its validity.

Silsbee [4] put forward the hypothesis that the magnetic field due to the threshold value of the current on the surface of the resistance (*i.e.* the place where this magnetic field reaches its maximum value) is exactly equal to the (transversal) magnetic threshold value at the same temperature. Experiments made

by Kamerlingh Onnes and Tuyn [5] confirm this supposition. In all these experiments all the values of the field intensities must, of course, be corrected for the intensity of the terrestrial magnetic field. Thus the phenomenon of the threshold current need not be regarded as a new phenomenon, to be explained by heating or otherwise, but is a direct result of the threshold magnetic field.

§ 3. *Influence of elastic deformation on superconductivity.* This phenomenon has been investigated by Kamerlingh Onnes and Sizoo [6]. The influence of elastic extension on the vanishing point has been investigated on tin, and that of elastic compression on tin and indium.

The result of the measurements was that stretching a wire was conducive to the appearance of the superconductive state (Fig. 4); a tension of 2·5 kg./mm.² within the limits of elasticity raises the critical temperature of tin by about 0·007° K. Hydrostatic pressure on a tin wire, however, causes a displacement of the transition curve to lower temperatures; the displacement for a hydrostatic pressure of 3 kg./mm.² amounts to 0·005° K. The results with indium are shown graphically in Fig. 5. Both these results were unexpected, because at normal temperatures an increase in pressure lowers the resistance and a tensile stress within the elastic limit increases the longitudinal resistance of the metal.

§ 4. The distribution of electric currents in superconductive circuits is determined by *Lippmann's* rule: *The number of magnetic lines of force enclosed by a closed superconductive circuit is constant* [7]. When, for example, in the time dt the number of lines changes by dn, a permanent current (resistance zero) is induced in the circuit. If the number of lines of force due to this current is dn^1, then

$$\frac{dn}{dt} + \frac{dn^1}{dt} = i.r = 0$$

$$\therefore d(n + n^1) = 0$$

$$\text{or } n + n^1 = \text{constant.}$$

Sizoo [8] has tested Lippmann's rule on the distribution of a current in two parallel tin wires of different diameter (Fig. 6). In the non-superconductive state this distribution is fixed by the ratio of the resistances. When now the wires were cooled till below the transition point of Sn, the magnetic needle, which was the indicator for the distribution of the current, did not change, though both wires had now the same resistance (zero). The external current was then broken, but still the needle did not change its position.

Very interesting experiments on induced currents in a closed superconductive circuit have been carried out by Kamerlingh Onnes and Tuyn [9]. They investigated the diminution of the currents with the time, for this diminution is a test for a possible small resistance in the superconductive state. The apparatus (Fig. 7) was based on the change of the electrodynamic forces between two superconductors and consisted therefore of a system of two superconductive (Pb) rings. The exterior ring B is fixed, but the interior ring A can be turned by means of a glass rod C and a spring D. Spring D can be turned separately by a torsion head. When the cryostat was

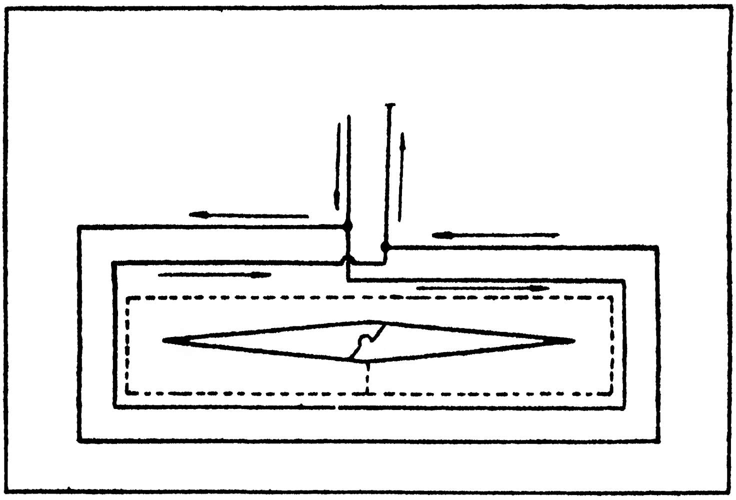

FIG. 6.

filled with liquid helium and the two rings were in the superconductive state (transition point of Pb is 7·2° K.), a magnetic field was switched on. The lines of force were perpendicular to the planes A and B. The magnetic field was stronger than the magnetic threshold value at the boiling-point of helium, so that the induced currents died out (superconductive state was disturbed). When the magnetic field was diminished to zero, persistent currents were induced, whose magnetic field was equal to the threshold value (from the moment that the external field is smaller than the threshold value, the rings become superconductive and Lippmann's rule must be applied). By means of the torsion head the ring A is turned 30°, controlled with mirror G. It was necessary to turn the torsion head through an angle greater than 30°. From this it followed that persistent currents existed. The turning of mirror G with the time is now an indication of a diminution of the electro-dynamic

forces between the rings and therefore for a residual resistance in the superconductive state. The correction for slipping of the torsion head with the time is determined with another mirror I. The result of the experiments was that the currents remained constant to 1 : 80,000 per hour. A possible residual resistance below the transition point must therefore be smaller than $10^{-11} \times$ the resistance at 0° C.

By a similar experiment the paths of the persistent currents in the metal were investigated. Ring A in the preceding experiment was replaced by a sphere of lead, and the diminution of the electro-dynamic force was observed to be of the same order as before. From this we may conclude that the paths of persistent currents are fixed in the metal.

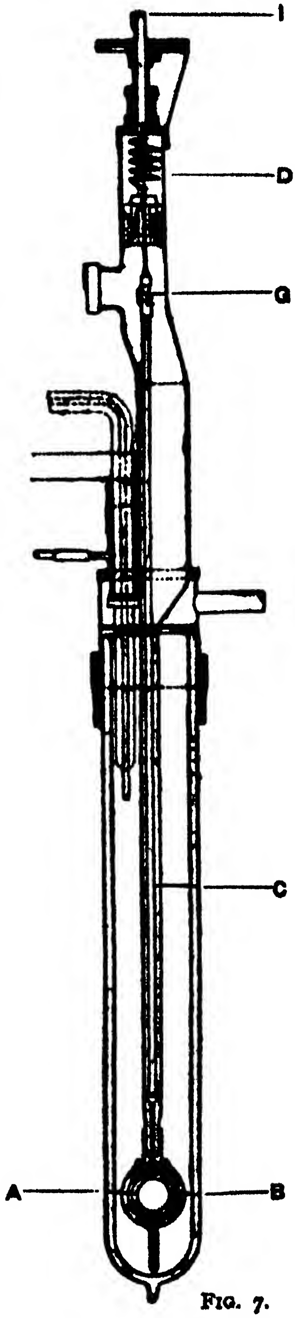

FIG. 7.

If it is impossible to bring a material to the form of a wire because the physical properties are unfavourable for this purpose, or that the quantity of material is insufficient, then we can use the properties of persistent currents to investigate its superconductivity. If we have, for example, the material in the form of a powder, then we can induce in the different grains in the former way persistent currents. Each of these grains gets in this way a permanent magnetic moment, and we can show the resulting magnetic moment by means of a magnetic needle, placed outside of the helium cryostat. This method has been tested with grains of lead, and in this way it has been shown that germanium and grey tin do not become superconductive above 1·8° K. [10].

§ 5. Of the highest importance to the phenomenon of the superconductivity is the crystal lattice of the different superconductors. For example, tin is a very good element to demonstrate this assertion, as the metal is

known in two forms, as white tin (tetragonal lattice) and as grey tin (cubic lattice). This last form is more stable at low temperatures. White tin becomes superconductive at 3·71° K.; grey tin is not superconductive above 1·8° K.

Moreover, de Haas and Voogd have investigated the influence of the crystalline state of a tin wire on its thermal transition curve [11]. They found that the resistance of a polycrystalline wire vanished at the transition point within 0·03° (Fig. 8), whilst the resistance of a good single crystal wire vanished within 0·002° (Fig. 8). These authors showed also

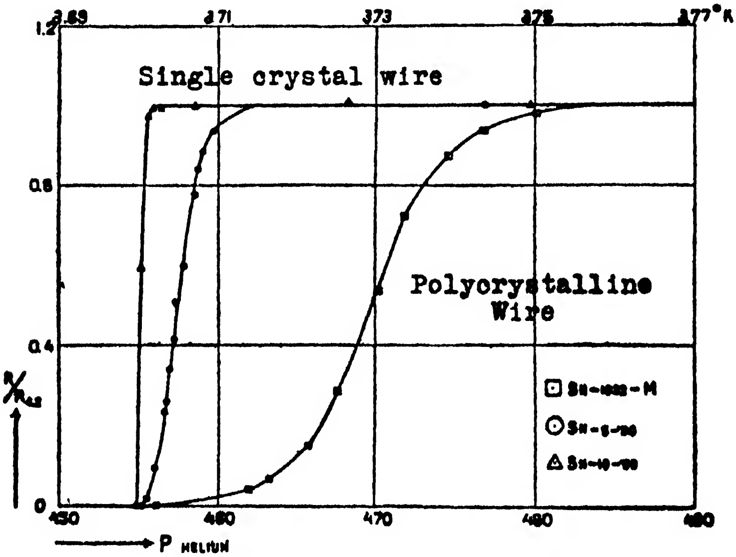

Fig. 8.

that the transition temperature of a tin single crystal is independent of the orientation of the tetragonal axis of the crystal with respect to the electric current. The behaviour of a polycrystalline wire cannot therefore be explained as the sum of the different effects caused by random orientations. We may conclude from this that superconductivity is a discontinuous phenomenon, and that the small temperature interval in which the phenomenon mostly takes place is caused by other circumstances, such as stresses between the crystallites, etc. (Section II, § 2).

§ 6. McLennan, Burton, Pitt, and Wilhelm have investigated superconductivity with alternating currents of high frequency [12]. The principle of the method employed in these experiments was very ingenious (Fig. 9). A resonance circuit has been constructed, consisting of a superconductive self-inductance and a condenser of the same material. This

resonator was placed in a helium cryostat. High-frequency currents were induced in this resonator by a generator outside the cryostat. The magnitude of the currents induced in the resonator was measured by the reaction on the generator oscillations. The indicator for this reaction was the mean plate current. A simple calculation shows that the variation

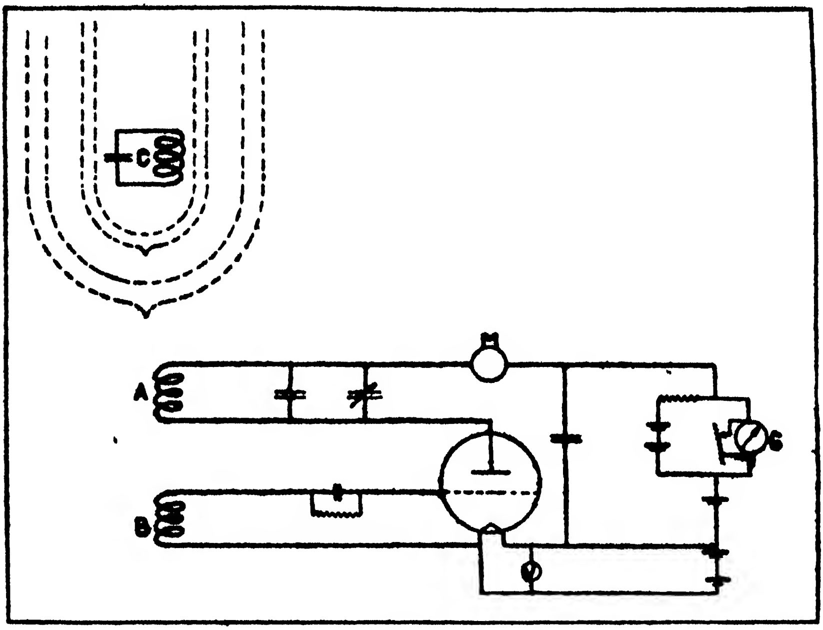

FIG. 9.

in the plate current Δi_p is inversely proportional to the alternating current resistance of the resonator :

$$\Delta i_p = \frac{\text{constant}}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}$$

In this formula R is the ohmic resistance (corrected for skin effect, L the self-inductance, C the capacity of the condenser, and ω the frequency of the induced oscillations. In case of resonance of generator and resonator

$$\Delta i_p = \frac{\text{constant}}{R},$$

so that when the resonator circuit becomes superconductive, there must be found a large change of the plate current. In these experiments the Dewar flasks must remain unsilvered, because this metallic screen would disturb the whole phenomenon. In experiments with a tin resonator it was found that a current

of frequency of 10^7/sec. lowered the transition point by 0.1°. With tantalum and lead analogous results have been obtained.

From these results McLennan has drawn the conclusion that polarisation and orientation effects play a prominent part in superconductivity. All these high-frequency measurements are, however, very difficult, and it is desirable that the results should be verified by other methods of measurement.[1]

Section II: The Superconductivity of Alloys

§ 1. In general we can divide the homogeneous alloys into two groups: the group of the mixed crystals (or solid solutions) and that of the compounds. Though different metallurgists give different definitions of compounds and mixed crystals, we may say, in general, that in a compound there is a regular distribution of both kinds of atoms over a common lattice. If, on the contrary, the atoms of the two components are statistically distributed over the lattice, we will speak of a mixed crystal (or solid solution). If we have, for example, a solid solution of 10 atoms of Cd in 90 of Hg, we have a Hg lattice in which 10 per cent. of the Hg atoms are replaced by Cd atoms in a statistical way. We will now discuss the different possibilities separately.

(*a*) Solid solutions of two superconductors are superconductive. For example, Meissner and his collaborators have investigated the system In–Pb [15]. The metallographic diagram of state shows that In and Pb form an uninterrupted series of mixed crystals (both elements have the same lattice and approximately the same lattice constant). Meissner found that the transition points of the different crystals change continuously with the composition. Analogous investigation has been made by this author with the systems Pb–Hg; In–Tl; and Sn–Tl [16].

(*b*) Solid solutions of a superconductor in a non-superconductor will in general not become superconductive, whilst they have the crystal lattice of the non-superconductor.

(*c*) Solid solutions of a non-superconductor in a superconductive metal. We can study the different results very

[1] McLennan and his collaborators [13] have investigated the superconductive state of a tantalum resistance when a direct and a high-frequency current were flowing simultaneously in the specimen. The experiments showed that in this case the transition temperature for both currents was the same, and that this temperature was determined by the ratio of the magnitude of these currents. Silsbee, Scott, Cook, and Brickwedde [14] have measured the influence of high-frequency currents on the superconductivity of a tin wire in a direct way. They used frequencies to 10^6 sec. and found the transition point to be the same as when measured with direct currents. The conclusion of these authors was that their results are not necessarily conflicting with McLennan's measurements.

well by considering the work of de Haas and Voogd on the superconductivity of the eutectics of Sn and Bi, Sn and Zn, and Sn and Cd [17]. These eutectics consist of two solid solutions, namely: a solid solution of each component in the other one. The solid solution of the superconductor in the

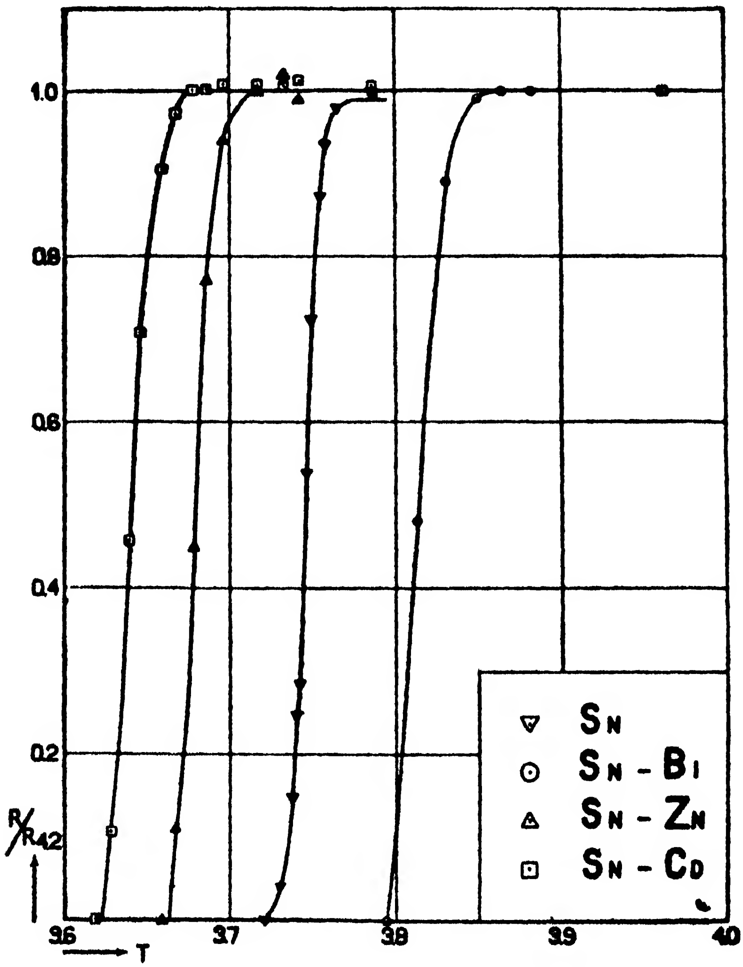

Fig. 10.

non-superconductor will not become superconductive, but the other solution has the lattice of the superconductive component, though somewhat disturbed by the atoms of the other component. This solution will become superconductive, but there are still two possibilities: the transition point of the pure superconductor may be lowered or raised by the non-superconductor. Fig. 10 shows the transition curves of the different

eutectics (and in our case of the solid solutions of the elements Bi, Zn, and Cd in Sn). We see that Bi raises the transition point, whereas Zn and Cd hinder the superconductivity of Sn. Another research has been made by de Haas and de Boer [18]. They investigated the influence of Cd (non-superconductor) on the superconductivity of Hg. The constitutional diagram of this system shows that Cd and Hg form a solid solution

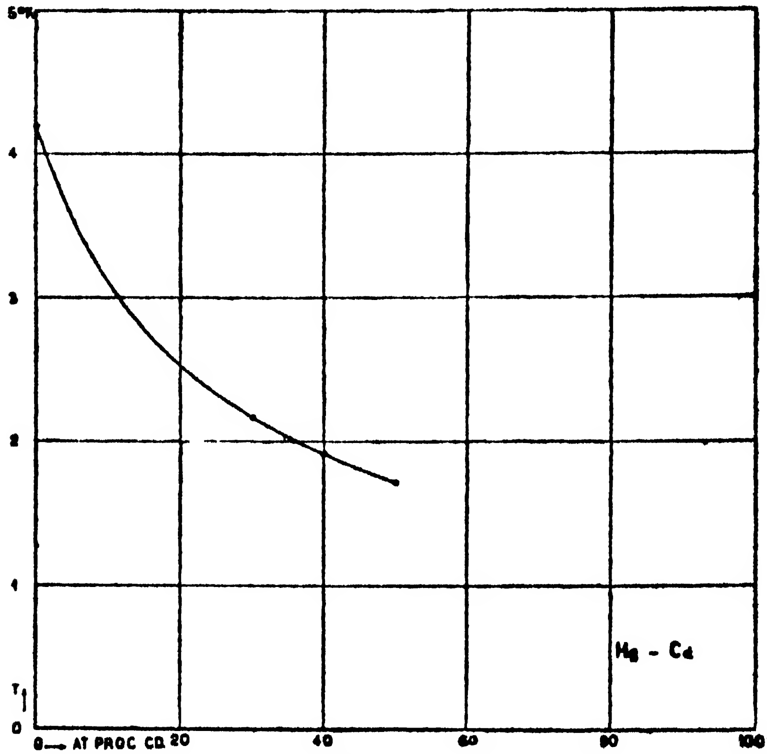

FIG. 11.

up to 60 atoms per cent. Cd. Crystals consisting of a solution of Cd in Hg, and therefore crystallised in the rhombohedric Hg lattice, have been investigated. The result is shown in Fig. 11. From this we may conclude by extrapolation that pure Cd, if it could crystallise in the rhombohedric Hg lattice, would have a transition point above 1° K. Measurements with the ordinary Cd have shown that it has a transition point below 1° K. This result shows again the great influence of the crystal lattice on the phenomenon of superconductivity.

(*d*) Solid solutions of two non-superconductors will not become superconductive.

(*e*) In Leiden, Berlin, and Toronto a large number of superconductive compounds have been discovered. They consist of two superconductors (Pb_2Tl_7, etc.), one superconductor and another metal (Bi_5Tl_3), or two non-superconductive metals (Au_2Bi) [19]. Especially this last case (cubic face centred lattice) is very interesting.

Meissner discovered [20] the superconductivity of MoC, TaC, TiC, NbC, TiN, TaSi, *i.e.* of compounds of a superconductive metal and non-metallic element. Among these, NbC has the highest known transition point : 10·1° K.

Moreover, Meissner found the superconductivity of CuS, MoC, WC, VN, ZrN, ZrB, compounds consisting of two non-superconductors, one of which is non-metallic [21].

§ 2. With these results we can explain an interesting phenomenon : the influence of superconductive impurities on the resistance curve of a metal. Here we must discriminate between two cases :

(*a*) The superconductive impurity does not form a solid solution with the metal. Between the crystallites we have, then, thin layers of superconductive impurities. As far as these layers form a united path, we have a short circuit through the metal at the transition temperature of the impurity. Here we have, however, a complication, because the current density in these thin layers is very high and the superconductivity may be disturbed (Section I, § 2). These layers will lose their resistance only when the magnetic threshold value is higher than the magnetic field of the current through them. Where the layers are thick the current density is small and they will become superconductive at the transition point of the impurity. The thin places will become superconductive only at lower temperatures. We must also expect that below the transition point of the impurity the resistance disappears in a certain interval that is larger when the current used is larger.

(*b*) The superconductive impurity forms a solid solution with the metal. During the crystallisation of the material concentration differences between the nucleus and the boundaries of the several crystals arise. In general a greater concentration of impurities exists on the boundaries than in the nucleus of the crystallites. If the transition point of these solid solutions is higher than that of the pure metal, we may have short circuits through several boundary layers of the crystals. The influence of the current density is here the same as in the former case.

An example of both effects is the resistance curve of phosphor-bronze. Below 7·2° K. there is a large diminution of the resistance of this material. For that reason it is used as a secondary thermometer at the temperatures of liquid helium [22].

These facts show that a good characteristic for the homogeneity of a mixed crystal or for the purity of a superconductor is, that the discontinuous change in its resistance takes place very steeply, in some hundredths of a degree only.

§ 3. Just as in the case of pure metals, the superconductivity of alloys may be disturbed by a magnetic field. There is only one essential difference: we can establish as a general rule that for superconductivity alloys the magnetic threshold value increases more rapidly with decreasing temperature than in the case of pure metals. Fig. 12 shows graphically the dependence

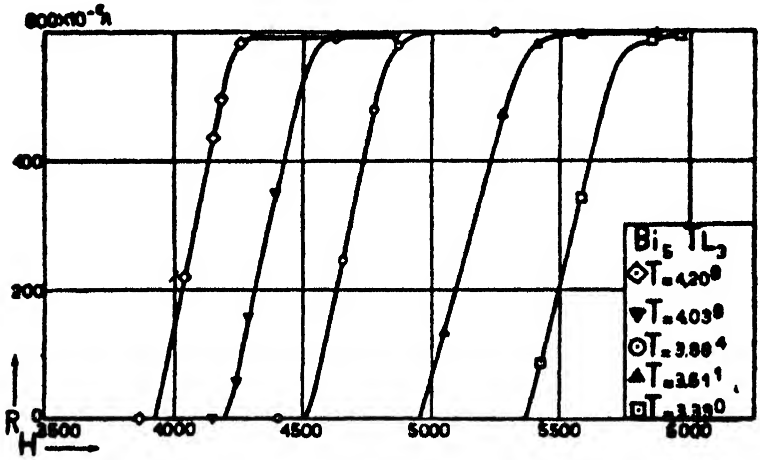

FIG. 12.

of the resistance on the magnetic field for Bi_5Tl_3, at different temperatures, whereas Fig. 13 is the graph of magnetic threshold value and temperature for Bi_5Tl_3 and for Pb.

Bi_5Tl_3 becomes superconductive at 6·4° K., so that the direct determination of this point is rather difficult (it must be made in a vapour-cryostat). We can, however, find the point by extrapolating the curve in Fig. 13 towards the value $H = 0$. The direct determination agrees very well with this extrapolation.

As a remarkable case we may mention that a solid solution of 35 per cent. Bi in Pb (transition point 8·8° K.) is still superconductive in a magnetic field of 21·150 gauss at 1·88° K. Perhaps the low-temperature laboratories can use this material to obtain strong magnetic fields without any heat development (because it is a superconductor). The method is very simple: a coil of this material must be immersed in a cryostat with liquid helium at a temperature below 2° K.

Section III : Relations between Superconductivity and other Physical Phenomena

§ 1. Kamerlingh Onnes and Tuyn [23] have investigated the superconductivity of lead isotopes. They found the same transition point for ordinary lead and for uranlead. Because isotopes have the same electronic shells and the conductivity is determined by the outer electrons, we can understand this result.

§ 2. Röntgenographic experiments done by Kamerlingh Onnes and Keesom [24] concerning the crystal lattice of a

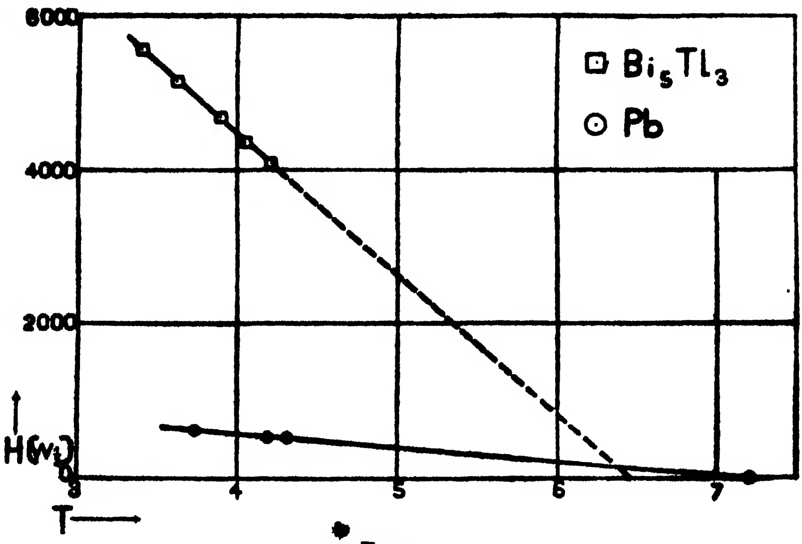

Fig. 13.

superconductor showed that the lattice does not change when the transition temperature is passed.

§ 3. Kamerlingh Onnes [25] investigated the contact resistance between two superconductors. He used the method of persistent currents : the ends of a superconductive coil (Pb) were pressed together ; in this coil there could be induced persistent currents. From this it follows that the resistance of the whole circuit, and therefore the contact resistance between the ends, was zero. Meissner and Holm [26] have measured the contact resistance between two different superconductors (Pb and Sn). They used the direct method of measuring resistances and found that the contact resistance became zero at the lowest transition point. Furthermore, it remained zero when the contacts were moved. The superconductivity of

this contact resistance was disturbed in the ordinary way by great densities of the electric current.

§ 4. De Haas and Kinoshita [27] have investigated in a very sensitive way the rigidity, or the torsion modulus, of Sn and Hg wires. They found no change in the rigidity by passing the transition temperature of the wires. Because all elastic constants are connected in a simple way with each other, it is probable that other elastic constants also remain unchanged in going from the non-superconductive to the superconductive state.

§ 5. The absorption of electronic rays by superconductive layer (Pb) has been investigated by McLennan [28]. He found no change in the absorption when passing the transition point.

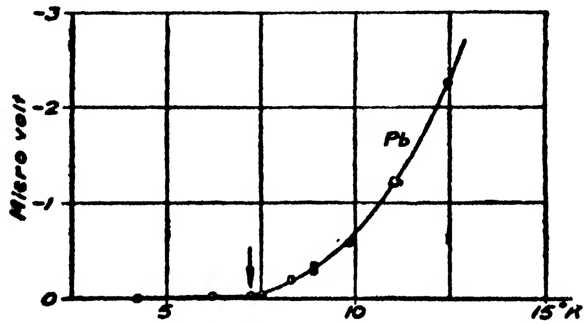

FIG. 14.

Meissner and Steiner [29] made experiments on the absorption of very slow electrons by a Sn layer. Even for these electrons there was no change in the absorption when the vanishing temperature was passed.

§ 6. McLennan has also investigated the possible variation of the photo-electric effect with temperature at low temperatures, particularly in the case of lead [30]. He concluded from his experiments that the photo-electric current does not show an abrupt change at the transition point.

§ 7. As to the thermo-electric force of a superconductor against a non-superconductor or against another superconductor two investigations exist: one of Meissner [31] and one of Borelius, Keesom, Johansson, and Linde [32]. Meissner investigated the couple Sn–Pb. He observed that this couple gives no thermo-electric force when both metals are in the superconductive state. Observations of the other investigators are not in contradiction with this result. Further, it must be mentioned that Borelius measured the thermo-electric forces for lead (to 1·7° K.) and tin (to 4·8° K.) against a certain silver alloy (Fig. 14). The authors conclude that the

thermo-electric force per degree (and hence the Thomson effect) changes rapidly in the neighbourhood of the transition point and is very small in the superconductive state. A sudden change at the transition point has not been found, but the thermo-forces at these low temperatures are very small and therefore rather difficult to measure.

§ 8. The thermal conductivity of superconductors has been investigated by de Haas and Bremmer [33]. The thermal resistance-curve of all the metals that have been investigated shows a minimum value that is displaced towards lower temperatures when the purity of the metals is increased. The thermal resistance curve of In shows a small sudden diminution

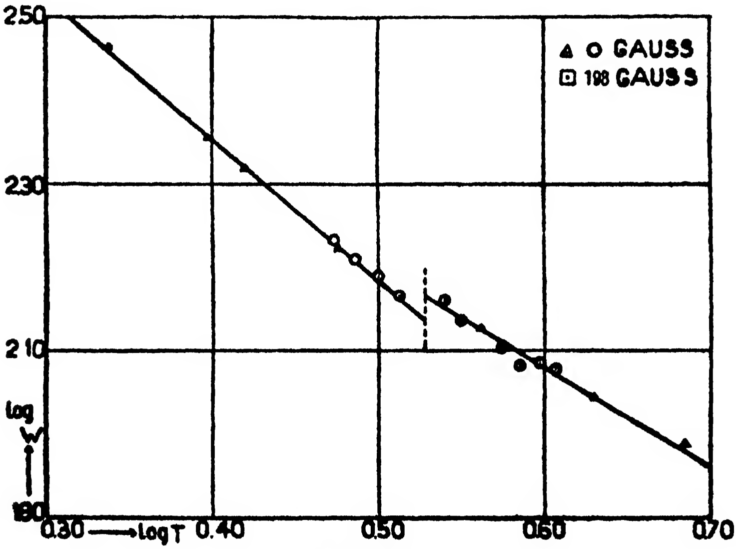

FIG. 15.

of the thermal resistance at the transition point of this material (Fig. 15). In the superconductive state the thermal resistance is affected by a magnetic field higher than the threshold value at that temperature. The magnetic field *diminishes* the thermal resistance of the metal in the superconductive state. (The electrical resistance is increased.) The thermal resistance of superconductive alloys ($PbTl_2$) shows analogous results.

§ 9. Keesom and v.d. Ende [34] have investigated the specific heat of tin. They concluded that the atomic heat of tin near 3·7° K. changes rapidly, so that just below 3·7° K. the atomic heat is larger than just above. New measurements have been made by Keesom and Kok [35]. The result is that between 3·70° K. and 3·72° K. the atomic heat of tin decreases from a value of 0·0078 to a value of 0·0054. The change of

the specific heat coincides also with the transition of the metal to the superconductive state. This conclusion is corroborated by the fact that when the superconductive state is disturbed by means of a magnetic field the sudden change in the specific heat disappears.

In conclusion, I should like to thank Prof. Dr. W. J. de Haas for his kindness in looking over the text.

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LOSCHMIDT'S NUMBER

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LOSCHMIDT's number, N, is defined as the number of atoms in a gram-atom or the number of molecules in a gram-molecule.[1] More than eighty different experimental determinations of this number have been made [1], and as it is a basic atomic constant its most probable value is of great importance in atomic physics. It is, therefore, the purpose of this article to outline the main methods by which Loschmidt's number has been evaluated, and to give some indication of current opinions of its most probable value.

Although as early as the seventeenth century Boyle had attempted to estimate the size of atoms, it was not until 1865 that the first successful attempt was made, by the Viennese physicist Loschmidt, to calculate the number which bears his name. This number is, by virtue of its definition, the same for atoms and molecules of all kinds. Though molecules may vary in size, shape and mass, the number of molecules in a gram-molecule is a universal constant for all solids, liquids and gases, elements and compounds.

Loschmidt's method was based on the kinetic theory of gases, which had been developed with great success largely by the efforts of his contemporaries, Maxwell and Clausius.

In the kinetic theory, the molecules of a gas are supposed to

[1] This number is frequently referred to as "Avogadro's Number," the term "Loschmidt's Number" being then reserved for the number of molecules in a cubic centimetre of a gas under standard conditions. Unfortunately, these designations are often interchanged. Avogadro's important hypothesis on the identity of the numbers of molecules in equal volumes of different gases at the same pressure and temperature was formulated in 1811, and is appropriately associated with his name; but Avogadro made no quantitative estimate of either of the above-mentioned constants. The first actual estimate of the number of molecules in one cubic centimetre of a gas under standard conditions was made in 1865 by Loschmidt, and from this the number of molecules (atoms) in a gram molecule (atom) was later evaluated. From the quantitative view-point it thus seems preferable to speak of "Loschmidt's number per gram-molecule (atom)," and of "Loschmidt's number per cubic centimetre," as is almost invariably done in the German scientific literature. This terminology avoids ambiguity, and has been adopted here.

be hard elastic spheres moving rapidly and unceasingly in all directions. When two molecules collide, a redistribution of energy takes place, and the molecules rebound in different directions with new velocities. The movements of individual particles are governed solely by chance, and from these assumptions Maxwell was able to deduce that the viscosity of a gas is given by the relation :

$$\eta = \frac{1}{3} \rho v l \quad . \quad . \quad . \quad . \quad (1)$$

where ρ is the density of the gas,
v is the average velocity of the molecules,
and l is the mean free path, or average distance between two impacts.

He was also able to show that if each molecule is a sphere of diameter σ, then :

$$l = \frac{V}{\sqrt{2}\pi N \sigma^2} \quad . \quad . \quad . \quad . \quad (2)$$

where N is Loschmidt's number, and V is the gram-molecular volume.

Since η and ρ are known with accuracy, these two equations can be solved for $N\sigma^2$, but to find either N or σ, one more equation is still necessary. To obtain this, Loschmidt assumed that if a gas were condensed, its molecules would be very closely packed, so that the volume of the molecules in a gram-molecule could be regarded as approximately equal to the volume of the liquid formed on condensation. This gave the third equation for finding N. The result is really a lower limit for the value of N, because it is very doubtful whether the molecules of a liquid at ordinary temperatures can truly be regarded as small spheres in actual contact ; it is more probable that they possess some slight freedom of movement, which would make them seem to be slightly larger in volume. The most reliable data give, for mercury, $N > 44 \times 10^{22}$.

Van der Waals' equation leads to a more exact relation between N and σ, since the constant b in that equation is of the form :

$$b = \frac{2}{3} \pi N \sigma^3 \quad . \quad . \quad . \quad . \quad (3)$$

From this Perrin has found for mercury $N = 62 \times 10^{22}$, while Ghose has obtained the same number for helium.

The hypotheses on which the kinetic theory rests render these calculations liable to considerable error, although the molecules of monatomic gases are most likely to approximate to perfect spheres, and thus give the most reliable results [2].

Brownian Movement

More direct methods of finding N have been developed from the Brownian movement in liquids. The random movements of tiny particles suspended in a liquid strongly resemble the supposed movements of gas molecules in the kinetic theory. In fact the motion is due to impacts between the visible particles and the invisible molecules, and for feeble concentrations the pressure p exerted on the walls of the vessel by the particles obeys the gas law, if it is written in the form :

$$p = \frac{\mathrm{RT}c}{\mathrm{N}m}$$

where R is the gas constant per gram-molecule,
c is the concentration in grams per c.c.
and m is the mass of a particle.

It follows, therefore, that the particles of a colloid in dilute suspension should exhibit in equilibrium a similar statistical distribution to the molecules of a perfect gas in equilibrium under its own weight. In other words, if n and n_0 are the numbers of particles present at any instant in equal areas of two horizontal layers in the liquid, one at a height h above the other, then :

$$n = n_0 e^{-\frac{\mathrm{N}}{\mathrm{RT}}mgh} \quad . \quad . \quad . \quad . \quad (4)$$

provided that n and n_0 are very large numbers.

If measurements are made of the displacements which a number of uniform particles undergo in any given direction in a second, they will have widely differing values, since they are subject to the laws of chance. But, as Einstein showed in 1905, the mean square displacement $\overline{\Delta^2}$ will have a very definite value connected with the viscosity of the liquid η, and the radius of the particles a, by the relation :

$$\overline{\Delta^2} = \frac{\mathrm{RT}}{\mathrm{N}} \cdot \frac{1}{3\pi\eta a} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

He also showed that if D be the coefficient of diffusion,

$$\mathrm{D} = \frac{\mathrm{RT}}{\mathrm{N}} \cdot \frac{1}{6\pi\eta a} \quad . \quad . \quad . \quad . \quad (6)$$

Each of these equations has been used to determine Loschmidt's number. In 1908, Perrin commenced a series of exhaustive researches with very uniform gamboge emulsions, obtained by fractional centrifuging. In succeeding years he varied the conditions of the experiment within wide limits, and in 1911 he published the results of counting over 13,000 grains

at four different levels in a very uniform suspension. From equation (4) he obtained $N = 68 \cdot 3 \times 10^{22}$. By measuring the displacements of 1,500 gamboge particles under a microscope, he also obtained from equation (5), $N = 68 \cdot 5 \times 10^{22}$, in good agreement with his other result ; but Brillouin, working under his direction, measured the diffusion coefficient of the granules, and his results give only $N = 44 \times 10^{22}$ [3].

A number of other workers have performed similar researches. The most reliable experiments on vertical distribution were performed by Westgren in 1914 [4] on the vertical distribution of extremely fine gold sols ; he obtained $N = (60 \cdot 5 \pm \cdot 2) \times 10^{22}$. From Einstein's displacement formula Svedberg, also working with gold sols, obtained $N = 60 \cdot 8 \times 10^{22}$ [5], while in 1923 Shaxby found $N = 60 \cdot 8 \times 10^{22}$ from uniform cultures of staphylococci [6].

Three or four workers have restricted themselves to examining the movements of one particle only. When numerous particles are observed, no matter how nearly uniform the

FIG. 1.

emulsion, the radius a is necessarily a mean value ; but when a single particle is studied, the radius a is a definite quantity. Nordlund devised a method of recording on a photographic plate travelling in a horizontal direction, the position, at regular intervals of time, of a minute mercury particle falling in water. The photographs, one of which is shown in Fig. 1, show beautifully the influence of both gravity and the Brownian movement ; and by comparing these two effects, Nordlund obtained $N = 59 \cdot 1 \times 10^{22}$.

The main diffusion results are: Svedberg, 58×10^{22}; Westgren, $65 \cdot 5 \times 10^{22}$ (both observers used gold sols) ; and Shaxby, 59×10^{22} from the diffusion of cocci.

Constantin has shown that more concentrated emulsions obey a distribution law based on van der Waals' equation, and has thus obtained $N = 60 \times 10^{22}$.

The Brownian movement has also been studied in gases. Einstein's displacement formula has been applied to the movements of charged mercury globules falling in air by Fletcher [7], who obtained $N = (60 \cdot 3 \pm \cdot 3) \times 10^{22}$; while E. Schmid [8] found from similar experiments on selenium particles $N = 59 \cdot 3 \times 10^{22}$.

An ingenious variation has been recently devised by Kappler. When a thin quartz fibre with a mirror attached to its lower end

is suspended in air at ordinary pressures, no marked movement of the mirror is noticeable. When, however, the pressure is reduced so that the effect of each individual air molecule impinging on the system plays its part, the mirror exhibits frequent irregular oscillations, which can be detected by means of light reflected from the mirror, and recorded on a photographic plate moving parallel to the axis of the wire. A typical plate is shown in Fig. 2. From the Brownian movement of quartz fibres, Kappler obtained $N = 60{\cdot}5 \times 10^{22}$ [27].

Although, with the exception of Perrin's work, the Brownian movement results are extremely consistent, the chief criticism seems to be that, since they all depend on measuring a statistical mean, they are all open to a probable error of $\pm \sqrt{\frac{2}{n}}$, where n is the number of observations taken. This means that in order

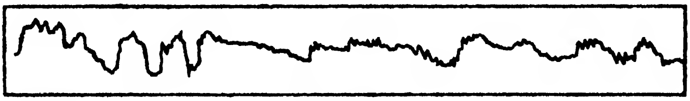

FIG. 2.

to obtain a result with a probable error within $\pm$ 1 per cent., at least 20,000 observations must be made ; or to obtain a probable error of ·1 per cent., no less than 2 million readings are needed ! This is quite irrespective of any other incidental errors.

Fluctuations

Loschmidt's number has also been obtained by measuring other fluctuating quantities [9]. Density fluctuations, necessarily a molecular phenomenon, gave $N = 60 \times 10^{22}$ (Constantin); critical opalescence yielded the value 75×10^{22} (Keesom and Onnes), and the critical miscibility of two liquids gave $N = 77 \times 10^{22}$ (Fürth) and $N = 62\text{–}65 \times 10^{22}$ (Zernike). These results are liable to large errors, and from our point of view can only be regarded as confirming the order of magnitude of N.

Linked with fluctuation phenomena is the explanation of the colour of the sky, which Rayleigh attributed to the scattering of the incident light by the individual air molecules in the atmosphere.

If E_0 is the intensity of the incident light of wavelength λ, and E is the intensity of the beam scattered in a direction at right angles to the primary beam, then :

$$E = E_0 e^{-hx} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\text{where } h = 22{\cdot}42 \times 10^3 \times \frac{32\pi^3(\mu - 1)^2}{3N\lambda^4} \qquad . \quad . \quad (8)$$

In these equations, s is the total length of the path traversed by the beam between the two points where the intensity is measured, and μ is the refractive index of the medium.

If the intensity is measured at regular intervals during the day, the corresponding values of s may be regarded as proportional to *sec* A, where A is the zenith distance of the sun. The experiment of course requires a pure atmosphere free from dust and water vapour. The ratio E/E_0 is generally obtained by means of a spectrophotometer. Dember [10] at Teneriffe found $N = 64 \times 10^{22}$, and Pacini [11] obtained $N = 62 \times 10^{22}$. Cabanes [12] studied the scattering of light in specially purified air and argon ; with the former he obtained 55×10^{22}, and with the latter, 69×10^{22}. These experiments involve measuring photometrically a ratio of the order of 10 million : 1, a matter of no small difficulty ; they can hardly be regarded as leading to precise values of N.

Fowle [13] has modified the method so that, instead of measuring E/E_0 directly, he correlates it with the quantity of water vapour present in the atmosphere, and then measures the atmospheric transmissibility. This process, though indirect, is very ingenious, and the result, which was obtained from readings taken over three years, was given as $N = (60{\cdot}6 \pm {\cdot}4) \times 10^{22}$. It is probably the most accurate value of Loschmidt's number at present obtained by means of Rayleigh's law.

Radioactivity

More direct methods have arisen from a study of radioactivity. It is well known that α-particles are doubly ionised helium atoms, and that only one α-particle is emitted from any one atom in the transformation of a radioactive substance. Radioactive decay is therefore a process in which the behaviour of single atoms may be studied, and the observer who counts α-particles emitted during the decay of a radioactive substance is actually counting individual atoms.

All the radioactive methods of finding Loschmidt's number depend on a value of Z, the number of α-particles emitted per second by 1 gram of radium. Z was first measured in 1908 by Rutherford and Geiger, who allowed α-particles from a standardised radium-C preparation to pass down a tube about 450 cm. long, through a mica window, and excentrically into a cylindrical vessel with a central insulated wire electrode. This wire was connected to a quadrant electrometer, while the outer case was raised to a high negative potential. When the gas pressure in the counter was reduced to 2 or 3 cm. of mercury, the influence of each α-particle entering it was magnified by ionisation by collision with the molecules of the residual gas.

Thus the entry of each α-particle into the counter produced a ballistic deflection of the electrometer. By counting the deflections produced by a radioactive preparation of known strength, Rutherford and Geiger found $Z = 3{\cdot}4 \times 10^{10}$. In 1918, Hess and Lawson [14], using a greatly improved counter, obtained $Z = 3{\cdot}72 \times 10^{10}$. More recently, in 1929, Ward, Wynn-Williams and Cave [15] designed a modification of the apparatus in which the ions produced by the α-particles were collected on a disc connected to the grid of the first valve of a five-valve circuit. The impulses could then be detected by means of a loud-speaker or recorded on a photographic film and counted at leisure. From a count of 92,000 particles they concluded that $Z = 3{\cdot}66 \times 10^{10}$.

Rutherford and Geiger also devised a means of measuring the charge transported by the α-particles. If the charge carried per second by the α-particles emitted from 1 gram of radium is Q, since each α-particle is a doubly ionised helium atom :

$$Z = \frac{Q}{2e}$$

where e is the electronic charge.

The most recent and probably the most reliable value of Z by this method was published by Braddick and Cave in 1928 [16]. By assuming Millikan's value of e, they obtained $Z = 3{\cdot}69 \times 10^{10}$.

The mean of the results of Hess and Lawson, Ward, Williams and Cave, and Braddick and Cave is $Z = 3{\cdot}69 \times 10^{10}$, and although for several years physicists seemed generally inclined to favour a lower value, $3{\cdot}4 \times 10^{10}$, it now seems probable that the higher value cannot be far from the truth.

To obtain N, however, more information is necessary. N could be found if we knew the volume V of helium in c.cs. at N.T.P. produced by 1 gram of radium per second, for then :

$$N = 22{\cdot}42 \times 10^{3} \times \frac{Z}{V} \quad . \quad . \quad . \quad (9)$$

Now the determination of V is a matter of extreme difficulty. The volume of helium given off by 1 gram of radium in equilibrium with its decay products is about 150 mm.^{3} per year, but as it is not usually possible to work with more than a small fraction of a gram of radium, the volume actually collected in an experiment is considerably less. A greater source of trouble is the part played by occlusion by the walls of the tube. Dewar [17] observed the growth of helium from two radium preparations, one experiment continuing for six weeks, and the other for two months. The method involved observing the increase

in the gas pressure due to the helium generated in an apparatus of known volume, and applying Boyle's law. His mean value was $V = 0{\cdot}48$ mm.^{3}, so that $N = 60 \times 10^{22}$. Boltwood and Rutherford [18] performed similar experiments; their mean result gives $V = 0{\cdot}43$ mm.^{3}, from which $N = 66 \times 10^{22}$. These numbers can hardly be regarded as accurate to more than the first significant figure.

A second radioactive method of finding Loschmidt's number arises from combining Z with λ, the decay constant of radium. λ has been found by Ellen Gleditsch from a careful study of the decay of four ionium preparations as $4{\cdot}14 \times 10^{-4}$ year^{-1}. This gives $N = 63{\cdot}5 \times 10^{22}$.

The third radioactive method of finding N depends on the volume V_r of 1 curie of radon at N.T.P. If λ_r is the decay constant of radon, then:

$$N = 22{\cdot}42 \times 10^3 \times \frac{Z}{\lambda_r V_r} \quad . \quad . \quad . \quad (10)$$

λ_r is known with a fair degree of accuracy as $0{\cdot}192$ day^{-1}, but the determination of V_r is again not an easy matter. The most reliable method was designed by Wertenstein, who measured the change in pressure in the apparatus due to purified radon from a standardised radium preparation by means of a decrement gauge. His result, $V_r = 6{\cdot}39 \times 10^{-4}$ c.c., leads to a value of $N = 61{\cdot}6 \times 10^{22}$, which is probably as reliable as any hitherto obtained by a radioactive method. But neither Z nor V_r is known so precisely that the resulting value of Loschmidt's number can be regarded as having a probable error of much less than 1 or 2 per cent.

More Accurate Methods of Finding Loschmidt's Number

It is interesting at this stage to review our position. Loschmidt's number has been determined by studying widely different phenomena, and there is remarkable agreement between the results. Indeed all the methods indicate a number in the region of $N = 61$–62×10^{22}. But none of the methods we have yet discussed can be regarded as a precision method, mainly because in each case the argument turns at some stage on estimating a statistical average, which to be accurately calculated needs a very large number of observations. The most direct of these methods are undoubtedly based on the Brownian movement, and a mean of the results of Nordlund, Svedberg, Shaxby, Westgren, Schmid, and Fletcher (giving equal weight to each observer), leads to $N = 60{\cdot}0 \times 10^{22}$, which ought to be very near the true value of Loschmidt's number.

It seems probable that the most exact value of Loschmidt's

number is to be obtained by some method which does not depend on the measurement of a fluctuating quantity, the individual values of which are distributed purely by chance. Four methods which satisfy this condition have been devised.

The oldest is based on the relation of Faraday's constant to the electronic charge. When in 1833 Faraday formulated his famous laws of electrolysis, he gave to the world the first indication of the atomic nature of electricity; for by his laws a gram-atom of every substance is always associated with the same quantity of electricity (or at least, a small integral multiple of the quantity associated with each monovalent element), whence each atom must always bear the same elementary charge e, or some simple multiple of it. In other words:

$$Ne = F$$

where F is Faraday's constant, or $9649 \cdot 1 \pm \cdot 1$ international em.u.

The history of the various methods of finding e, from Townsend's pioneer work ($e = 3 \times 10^{-10}$ es.u. : $N = 96 \times 10^{22}$), through Thomson's modification and Wilson's improvements, up to the classical work of Millikan, is too well known to be repeated here.

In 1917 Millikan gave the final results of his experiments as $e = 4 \cdot 774 \times 10^{-10}$ es.u. and $N = (60 \cdot 62 \pm \cdot 06) \times 10^{22}$. His experiments show remarkable consistency; for several years his work was examined for flaws by some of the keenest brains in Europe, and it has withstood every adverse criticism. Every link seemed substantiated by experimental evidence, and for over ten years Millikan's 1917 value of N was accepted by physicists as the best obtained at that time. In 1929, however, Birge [20] showed that a small correction was necessary, as Faraday's constant is given in international coulombs (based on the definition of an ampere as that quantity of electricity which, under standard conditions, will deposit 0·00111827 grams of silver per second), and Millikan's p.d. was read on a voltmeter calibrated in international volts. Now although the international units were originally intended to be exactly equal to the corresponding absolute units, and indeed seemed so when they were defined, more recent work has shown that there are, in some cases, slight discrepancies; for instance:

1 international coulomb = $(0 \cdot 99995 \pm \cdot 00005)$ absolute coulombs

and 1 international volt = $(1 \cdot 00046 \pm \cdot 00005)$ absolute volts.

These differences are slight enough, but they have changed Millikan's value to $N = (60 \cdot 64 \pm \cdot 06) \times 10^{22}$.

Birge recalculated e by using Millikan's readings and weighting them differently. The result is practically identical with Millikan's, and undoubtedly Millikan's value must be considered among the most reliable determinations of Loschmidt's number.

It is not generally known that other experiments of this type have been performed [21]. In 1914 Lee found $N = 60 \cdot 8 \times 10^{22}$, using Millikan's apparatus, whereas in Switzerland in 1913, Schidlof and Mlle. Murzynowska, working with a smaller condenser and a p.d. of only 100 volts (compared with Millikan's 3,000 volts) found $e = 4 \cdot 738 \times 10^{-10}$ and $N = 61 \cdot 1 \times 10^{22}$. Schidlof and Karpowicz obtained in 1915 $e = 4 \cdot 82 \times 10^{-10}$ and $N = 60 \cdot 0 \times 10^{22}$, while in the same year Targonski obtained $e = 4 \cdot 68 \times 10^{-10}$, giving $N = 61 \cdot 9 \times 10^{22}$. Though not so exact as Millikan's, these results are in good agreement with his and strongly enhance his value. Indeed a mean (unweighted) of all balanced droplet results gives $N = 60 \cdot 85 \times 10^{22}$, which is within one-third per cent. of Millikan's estimate.

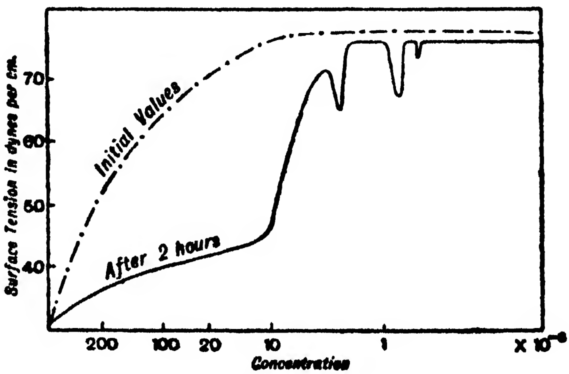

Fig. 3.[1]

The second method, which is independent of fluctuation phenomena, was devised by du Noüy [22], who made a careful study of the surface tension of dilute solutions of sodium oleate. His results are shown graphically in Fig. 3. The dotted curve was obtained by measuring the surface tension directly after preparing the solutions. The continuous curve was obtained from observations taken after the solutions had been allowed to stand for two hours. This curve exhibits three well-defined minima, which can only indicate unique arrangements of the molecules of the dissolved substance. It is well known that the dissolved molecules in very dilute solutions tend to form a monomolecular layer covering the whole surface of the liquid. Du Noüy supposes that if the concentration were so adjusted that in a given sample *all* the dissolved molecules were adsorbed in the surface layer, then the surface energy would be a minimum, and would give rise to a corresponding minimum in the surface tension.

There are three possible methods of packing the molecules in

[1] Reproduced by kind permission of the *Philosophical Magazine*.

the surface layer, the thickness of the layer corresponding to the length, breadth, and height of the molecule respectively. (Strictly speaking, the terms "length," "breadth," and "height" can hardly be applied to molecules, which are probably very irregular in shape; but here we are considering not the actual molecules, but the space they occupy when symmetrically packed with others.)

Let ρ = density of the dissolved substance,
A = area of the adsorption surface,
V = volume of the solution under examination,
and l_1 = thickness of the adsorbed layer corresponding to the first minimum on the surface tension curve, the concentration being then c_1

Then the total volume of adsorbed substance $= Al_1 = \dfrac{Vc_1}{\rho}$

$$\text{Hence } l_1 = \frac{Vc_1}{A\rho} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Similarly for the other two minima:

$$l_2 = \frac{Vc_2}{A\rho} \text{ and } l_3 = \frac{Vc_3}{A\rho} \quad . \quad . \quad . \quad (12)$$

Hence the number of molecules per c.c. $= \dfrac{A^3\rho^3}{V^3c_1c_2c_3}$

and if M = molecular weight of the adsorbed substance,

$$N = \frac{A^3M\rho^3}{V^3c_1c_2c_3} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

For sodium oleate, du Noüy found $N = (60{\cdot}04 \pm {\cdot}09) \times 10^{22}$. The principle of the method is extremely simple. The chief criticism seems to be that there is at present no evidence to justify the assumption that *all* the dissolved molecules are adsorbed in the surface. If this is not true, the calculated value of N is probably lower than the true value. At present du Noüy's work is unique, but the simplicity of the method makes it probable that, in the future, it will lead to very accurate values of N.

The most recent experimental values of Loschmidt's number rest on the discovery by Doan and Compton that X-ray wavelengths may be determined directly by means of ruled diffraction gratings. Before this discovery, all X-ray spectroscopy was based on the reflexion of X-rays at crystal surfaces, first observed by Sir W. H. and W. L. Bragg. They showed that reflexion takes place when the experimental arrangements satisfy the relation:

$$n\lambda = 2d.\sin\theta$$

where λ is the wavelength of the incident beam,
θ is the glancing angle (the complement of the angle of incidence in optics),
and d is the lattice constant of the crystal.

A more exact form of the relation takes into account the refraction of the X-rays at the crystal surface. This is :

$$n\lambda = 2d.\sin\theta\left(1 - \frac{1-\mu}{\sin^2\theta}\right) \quad . \quad . \quad (14)$$

where μ is the index of refraction.

Equation (14) connects λ and d. To determine either quantity one more equation is necessary. This involves Loschmidt's number, for in rock salt of molecular weight M and density ρ :

$$d = \left(\frac{M}{2\rho N}\right)^{\frac{1}{3}}$$

Actually, for accurate work, rock salt has been superseded by calcite, and the corresponding equation is :

$$d = \left(\frac{KM}{\rho N\beta}\right)^{\frac{1}{3}} \quad . \quad . \quad . \quad . \quad (15)$$

where K is the number of molecules in an elementary unit of the crystal and β is a quantity which depends on the slope of the crystal faces.

Until recently all X-ray wavelength measurements were based on equations (14) and (15) and an arbitrary value of N ; Millikan's was generally selected. But if an X-ray wavelength could be found by an independent experiment, Loschmidt's number could then be calculated.

Doan and Compton's discovery that X-rays can be diffracted by ruled gratings allows us to do this. The principle is the same as in the diffraction of visible radiation, although of course a photographic method has to be used. The angles to be measured are very small (only a few minutes of arc), so that the problem is now one of measuring small angles with a high degree of accuracy.

Two lines of attack have been devised. It is possible either to work in air with short wavelengths of 1 or 2Å, or *in vacuo* with longer wavelengths of 10–20Å. The former method gives smaller angular separation of the diffracted beam, but has the advantage of easier adjustment. Both methods have been used, the former by Doan and Compton ($N = 60{\cdot}60 \times 10^{22}$), Wadlund ($N = 60{\cdot}60 \times 10^{22}$), and Bearden [23], whose work was very thorough and painstaking. His result, $N = (60{\cdot}19 \pm {\cdot}03) \times 10^{22}$, is rather lower than Millikan's, and it seems difficult to attribute the discrepancy entirely to experimental errors.

Long-wave experiments have been performed by Bäcklin ($60{\cdot}34 \times 10^{22}$), Howe ($60{\cdot}19 \times 10^{22}$), and Cork ($60{\cdot}06 \times 10^{22}$), though it is doubtful whether any of these can be regarded as having the same accuracy as Bearden's work.

Relations between e, N, *and h*

In 1929, W. N. Bond [24] devised an ingenious method of calculating e (and hence N) from the various methods of finding Planck's constant h. There is no experiment by which h can be found without assuming an arbitrary value of e, but in all the various experiments from which Planck's constant has been found, the final calculation is based on an equation of the form :

$$h = Ae^{n} \qquad . \quad . \quad . \quad . \quad (16)$$

where A is an experimentally determined quantity, and n is an index which may be either 1, 4/3, or 5/3. Any two sets of experimental data involving different values of n could be solved for h and e (N being obtained through Faraday's constant). This is essentially what Planck did in 1902 when he found N by combining his radiation formula with Stefan's law. Bond has generalised the principle, and by solving 36 sensibly independent sets of experimental results gathered from widely different branches of physics, he has obtained the value, $N = (60{\cdot}54 \pm {\cdot}03) \times 10^{22}$. Birge, while accepting the principle, has questioned the choice of data ; he has made a very thorough recalculation with carefully chosen sets of results, and has obtained $N = (60{\cdot}62 \pm {\cdot}03) \times 10^{22}$ [25].

Conclusion

In reviewing the methods of finding Loschmidt's number, we cannot fail to be impressed by their great variety and the remarkable agreement among their results. But to decide on the most probable value is a matter of considerable difficulty, for while there can be little doubt about the first two figures, only three methods can reasonably be expected to give the third with reasonable precision. These are the balanced drop method, the X-ray method, and Bond's method.

The discrepancy between Bond's and Birge's results shows how important is the selection of data for this calculation. Birge's figure is, however, in very close agreement with Millikan's value, although the X-ray value is slightly lower.

The X-ray value has been the subject of much discussion. At one time it was suggested that possibly Millikan's result was too high, owing to some unsuspected source of error. But the close agreement with Birge's calculation makes that now almost impossible. It was also suggested that Bragg's theory

of crystal structure perhaps only represented a first approximation to the true form, and that really some kind of secondary structure was superimposed on it. But Bearden has recently redetermined N by a dispersion method based on an elaborate expression for the refractive index of quartz in terms of the wavelength of the incident X-radiation and $\frac{e}{m}$ ($1{\cdot}761 \times 10^7$ em.u.). The result is almost identical with Millikan's value, and appears to indicate that the optical theory of gratings is inexact when applied to X-rays. The question is, however, by no means settled.

On the other hand, no flaws have been detected either in the theory or the execution of Millikan's experiment, and the close agreement of his value with that calculated by Birge is strongly in favour of the most probable value of Loschmidt's number being at the present time:

$$N = (60{\cdot}62 \pm {\cdot}03) \times 10^{22}.$$

In conclusion, I wish to express my sincere gratitude to Prof. S. R. Milner, F.R.S., and Dr. R. W. Lawson for their guidance and encouragement while the material for this article was being collected.

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COLLECTED VALUES OF LOSCHMIDT'S NUMBER

Method.	Observer.	Remarks	Date	$N \times 10^{-22}$
Kinetic theory of gases	Perrin	Minimum value	1909	44
Van der Waals' equation	Perrin	From data for argon	1909	62
Theory of liquids .	G. Jäger	From mercury	1911	61·2
Vertical distribution of colloids in dilute solution	Perrin	Gamboge	1908	70·5
	Perrin	Gamboge	1911	68·2
	Perrin and Dabrowski	Mastic	1909	70
	Perrin and Bjerrum	In glycerine	1911	72
	Westgren	Gold sols	1914	60·6 ± ·3
Distribution in concentrated suspensions	Constantin	Gamboge	1914	60
Brownian movement of translation in liquids	Perrin	Gamboge	1911	68·8
	Svedberg	Gold sols	1911	62
	Zangger and Bohi	Mercury drops	1911	61
	v. Ettenreich	Mercury	1912	72
	Przibram	Mercury	1912	62·5
	Nordlund	Mercury	1914	59·1
	Seelis	Cinnobar	1914	72
	Shaxby	Staphylococcus	1923	60·8
Brownian movement of rotation	Perrin	Gamboge	1909	65
Brownian movement of quartz fibres	Kappler	—	1931	60·39
Diffusion . .	Einstein	Sugar solution	1906	65·6
	Svedberg	Mercury sols	1911	58
	Brillouin	Gamboge	1912	44
	Shaxby	Staphylococcus	1925	59
Fluctuations . .	Constantin	—	1914	60
	Keesom and Onnes	Opalescence	1911	75
	Furth	Miscibility of two liquids	1915	77
	Zernike		1915	62–65
Rayleigh's law .	Sella (and Kelvin)	Skylight	1902	39–150
	Bauer and Moulin		1910	45–75
	Dember		1916	64
	Pacini		1915	62
	Fowle		1914	60·6
	Cabanes	Argon	1920	69
Faraday's constant (early methods)	Townsend	—	1898	96
	J. J. Thomson	—	1903	86
Faraday's constant and Wilson's method of finding *e*	H. A. Wilson	—	1903	93
	Lattey	—	1909	62
	Alexejew and Malikow	—	1909	64
	Millikan and Begeman	—	1910	63
	Begeman	—	1910	62
Millikan's method of finding *e*	Millikan	—	1917	60·62 ± ·06
	Millikan	Recalculated	1930	60·64 ± ·06
	Millikan	Recalculated by Birge	1929	60·64 ± ·06
	Lee	Shellac drops	1914	60·8
	Ishida	Mercury drops	1923	60·64 ± ·17
	Schidlof and Murzynowska	Mercury drops	1913	61·1
	Schidlof and Karpowicz	Mercury drops	1914	60·0
	Targonski	Mercury drops	1915	61·9

COLLECTED VALUES OF LOSCHMIDT'S NUMBER—*continued*

Method.	Observer.	Remarks.	Date.	$N \times 10^{-22}$.
Roux's method .	Roux	—	1912	69
Brownian movement in gases	Fletcher	Millikan's apparatus	1911	57·5
	Fletcher	Millikan's apparatus	1914	60·3 ± 1·2
	E. Schmid	—	1920	59·3
Production of helium from radium	Dewar	$Z = 3{\cdot}69 \times 10^{10}$	1910	60
	Boltwood and Rutherford		1911	66
	Debierne		1914	68·7
Half-value period of radium	Boltwood		1908	76
	Meyer and Schweidler		1913	65·6
	Keetman		1909	68·3
	Ellen Gleditsch		1919	63·5
Volume of 1 curie of radon	Wertenstein		1928	61·6
Thin films . .	du Nouy		1924	60·04
X-ray wavelengths by grating	Doan and Compton	—	1924	60·6
	Thibaud	—	1926	60·6
	Hunt	—	1927	57
	Bäcklin	—	1928	60·34 ± ·19
	Wadlund	—	1928	60·60 ± ·09
	Howe	—	1930	60·19
	Bearden	Recalculated by A. H. Compton	1929	60·14 ± ·026
	Cork	—	1930	60·06
	Bearden	—	1931	60·19 ± ·03
Bond's method .	Bond	—	1931	60·54 ± ·03
	Birge	—	1932	60·62 ± ·03

RECENT DEVELOPMENTS IN THE TECHNIQUE OF THE ABSORPTION SPECTROGRAPHY OF LIQUIDS

By A. HARVEY, Ph.D., B.Sc.

The absorption spectra of liquids have long been of interest to biochemists and workers in related fields, but it is only within the last two or three decades that any very considerable advances have been made in this subject. Hartley [1], it is true, as early as 1879 showed that when properly handled the technique then available could yield valuable results, and he did striking work in determining the constitution of organic compounds for which ordinary methods of chemical analysis were not applicable. It is essentially correct, however, to state that most of the work done before the beginning of the present century (forming a considerable mass of literature) may be dismissed as valueless. This is due to the fact that the earlier observations of absorption were not quantitative, save for a few very important exceptions in the visual region. In observations of this type factors such as the variation with wavelength of (*a*) the intensity of the source, (*b*) the sensitivity of the photographic plate, and (*c*) the dispersion of the instrument, must be carefully allowed for, else very erroneous interpretations may be given to the spectrograms obtained; for example, the apparent maximum of absorption may be in a position quite different from that of the actual maximum. Kayser [2], as late as 1908, drew attention to the unsatisfactory nature of the work being done owing to neglect of such precautions.

Soon after this the subject received a considerable impetus from the introduction of the Sector Photometer by Twyman in 1913. This instrument was based upon a principle first employed by Henri [3], and its use rendered possible accurate absorption spectrophotometry throughout the whole of the visible and ultra-violet regions. The arrangement is as follows.

Two beams of light proceeding from the same source reach the spectrograph slit after having passed, in the one case, through a rotating sector of fixed aperture and, in the other, through a rotating sector whose aperture is variable from one exposure to another. The beam passing through the fixed

aperture also passes through a tube of known length containing the substance under examination. The varying absorption of this substance with wavelength will obviously have the effect of diminishing the intensity of the beam by varying amounts for different regions of the spectrum. The intensity of the other beam, as has already been indicated, can be altered by varying the aperture of the sector. Finally, by means of a suitable optical system the two beams are brought together (side by side) on the photographic plate. Examination of the plate will show that at one or more points the two spectra are of the same intensity, and from this it will be evident that for the wavelengths where the spectra match the optical density of the column of liquid is the same as that of the sector. A number of photographs are taken (a usual number is fifteen) with varying densities in the comparison beam, and from the data thus accumulated a density/wavelength curve is built up. Since the length of the absorption tube is accurately known, such a curve is readily converted into one of extinction coefficients/wavelengths.

A number of criticisms have been urged against this method, the most serious one being that the introduction of intermittency into the beams involves the making of certain assumptions about the nature of the photographic plate which do not meet with general acceptance. It is well known that an exposure given in instalments does not produce the same blackening of the photographic plate as does a continuous exposure of the same intensity with the same total duration. Also, reciprocity of time and intensity does not exist, that is to say that exposures for which the product of intensity and time is constant do not give equal blackenings on the plate unless the intensities are the same. In the case of the sector photometer it is assumed that these two factors cancel out. A very considerable mass of literature has risen up around these two phenomena of the photographic plate, and extraordinary contradictions are to be found in this. The latest work on the subject by O'Brien [4] confirms the original assumption upon which the instrument was put forward, that the two effects do cancel out. However, quite apart from the investigation of the characteristics of the photographic plate *per se*, a number of searching examinations have been made in which the results obtained by the sector photometer have been compared with those given by instruments of a totally different type (such as the Judd Lewis photometer, *vide infra*) in which intermittency does not enter, and also with instruments where the photographic plate is not used, and the recording is done by means of the eye or a photo-electric cell. Such examinations have been made by Baly, Morton and Riding [5] in England and by

Gibson and others [6] in America. These examinations, and various other unpublished ones made by the manufacturers, have shown that the results given by this instrument are identical with those given by instruments in which intermittency does not figure.

The point just discussed was the most serious objection made to the sector photometer, but a number of other features were also criticised, some of these being matters of design whilst others—such as the fact that the interposition of a rotating sector must perforce cut the available intensity to one-half—are inherent in the principle adopted. The Judd Lewis photometer was introduced in 1919 to overcome the objection to intermittency mentioned above. In this latter instrument the apertures through which the two beams pass are closed by quadrantal-shaped pieces of metal, and the optical density of the apertures depends upon the extent to which the quadrants are turned. The main drawback to this instrument is that the mechanism for varying the apertures is costly to make if it is desired to reach any high accuracy. A modified form of this photometer has now been perfected in which the variable aperture is simply a rectangle whose area is accurately controllable by means of a micrometer screw, whilst the speed is about double that of the Judd Lewis photometer. This new photometer, however, has already been described in these pages (see SCIENCE PROGRESS, p. 504, January 1933), and all that remains to be added here is that in spite of the developments we are about to describe, this modified model (the Spekker photometer) is the instrument to be used whenever the highest accuracy is desired. Particularly is this so when liquids of low optical density are under examination.

All of the methods so far described must be regarded as being fairly laborious and time-taking. With the sector photometer, for instance, the time occupied in the taking of the ten or fifteen spectrograms necessary for the drawing of the absorption curve is generally of the order of 30 to 40 minutes. Even with the Spekker photometer the same data requires 15 to 20 minutes for its accumulation. It is true that this time may be reduced by taking some of the photographs—those for the regions of high extinction coefficients—using lesser thicknesses of liquid, but the limit of advantage of such procedure is soon reached, necessitating as it does the filling and placing in position of fresh cells. Hence any method which would cut down considerably the time involved would be extremely welcome from the point of view of the labour saved. Quite apart from this, however, is the fact that if the substance under examination is one which changes rapidly upon irradiation, then the data obtained from exposures extending over

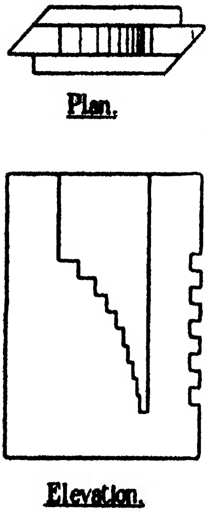
even 15 minutes may be completely meaningless. In other words, if a method could be developed whereby the exposures extended over not more than 1 minute, say, then a new field would be opened up for investigation.

Several attempts upon this problem have been made within the last year or so, and one of these attempts has been successfully developed up to the point where the necessary apparatus is now obtainable. We shall deal with this development first. The essential ideas were put forward in a paper by Twyman, Spencer and Harvey [7], and these have been further developed in a paper by Twyman [8]. Briefly, the variation in density—which in the earlier methods was obtained by discontinuously varying the density in the comparison beam and taking a photograph of the spectrum for each density employed—is transferred to the substance under examination by placing the latter in a wedge, or similarly shaped recess. A spectrogram taken with such a cell in front of the spectrograph slit would yield the familiar " wedge spectrum " such as was first employed for photographic purposes by Mees and Wratten [9]. A modification is introduced, however, in that a series of interruptions are imposed in the vertical direction so that a series of spectra are obtained each of which has passed through a different thickness of liquid. The intermediate spaces are filled in (during the same exposure) by a similar set of spectra obtained from the same light source, but with the difference that in this second set of spectra the radiation has not been subject to absorption by the liquid at all, but has been reduced in intensity by a known amount. This second set of spectra is obtained by passing a beam through a second cell containing the solvent (employed in making up the solution) and also through a rotating sector.

The cells employed are shown in the plate (A) and their construction is illustrated in Fig. 1. They are made from fused silica and, by placing the various surfaces into optical contact and then raising the cell to a high temperature, are welded into single solid pieces without the use of any cement. It will be noticed that the recesses containing the liquids are stepped—by this means the deviation and dispersion which would result owing to the beams entering the liquid at an angle (that of the wedge) are eliminated. The cell which is to contain the liquid under examination is notched at the one end whilst the comparison cell is quite plain.

The manner of using the cells will be clear from Fig. 2. The notched cell, containing the liquid whose absorption curve we wish to study, is placed nearest to the slit of the spectrograph. A beam of light from the source R is collimated by the lens C, strikes the first inclined face of the rhomb, and from there is reflected through the liquid to the opposite face. From there

the beam is reflected into the slit of the spectrograph, but only from that area of the face in which notches have not been ground; this constitutes the interruption in the vertical direction already mentioned. The second or comparison cell (F_2) is placed farther from the slit, but it behaves in a similar manner except that, since there are no notches ground in this cell, the whole of the beam is reflected towards the slit. Before



ADAM HILGER, Ltd., London.

FIG. 1.—Diagram of the notched echelon cell.

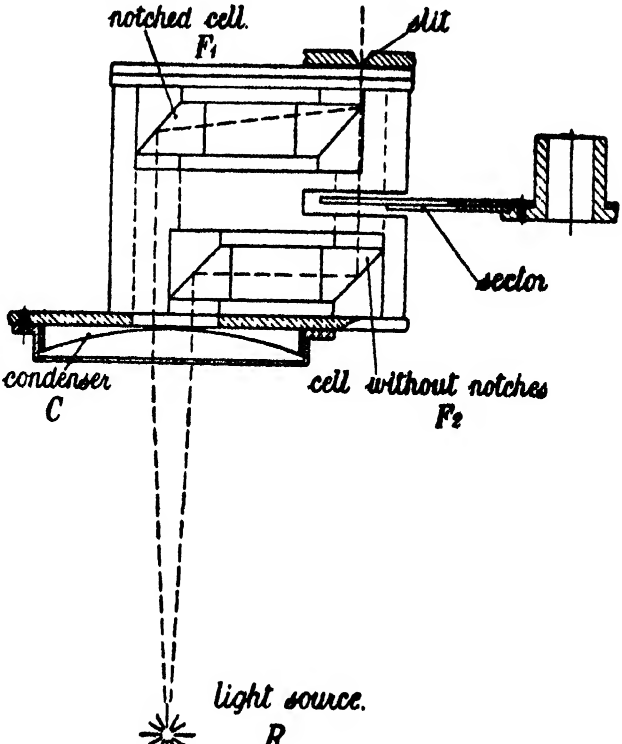
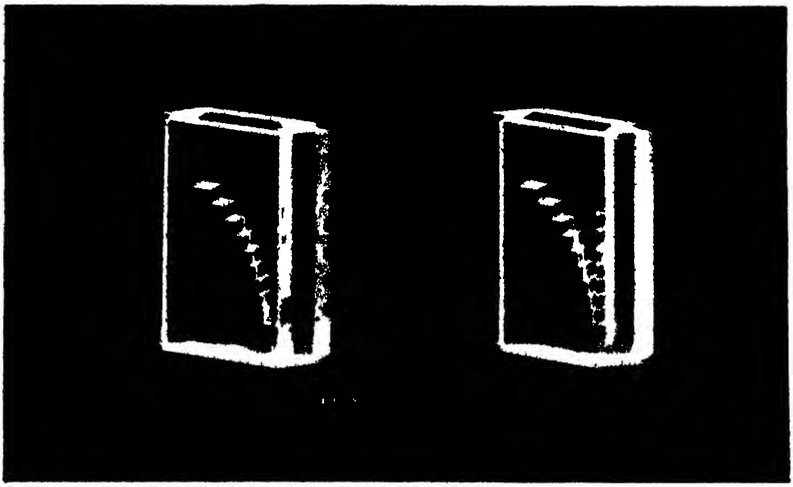


FIG. 2.—Diagram of cells in mount, with sector.

(Reproduced by kind permission of the Physical Society.)

reaching the slit, however, the first cell interferes with this beam, and only that part of the beam passing through the notches of the first cell reaches the slit. The beam from this comparison cell F_2 has also to pass through the rotating sector, and by this means the reduction of a known amount is imposed upon it. The set-up of the apparatus is shown at (B) on the plate, whilst the spectrogram obtained by a single exposure through such a set-up is shown at (C). It is essential at this point to emphasise that the spectrogram shown is obtained by



Notched cell Plain cell.

PLATE A.

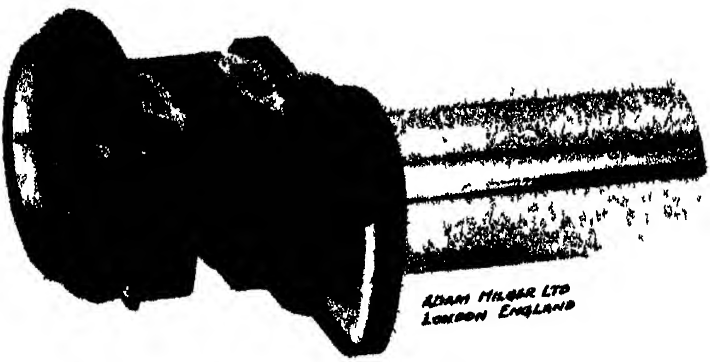


PLATE B

CELLS IN MOUNT ATTACHED TO SPECTOGRAPH SLIT.

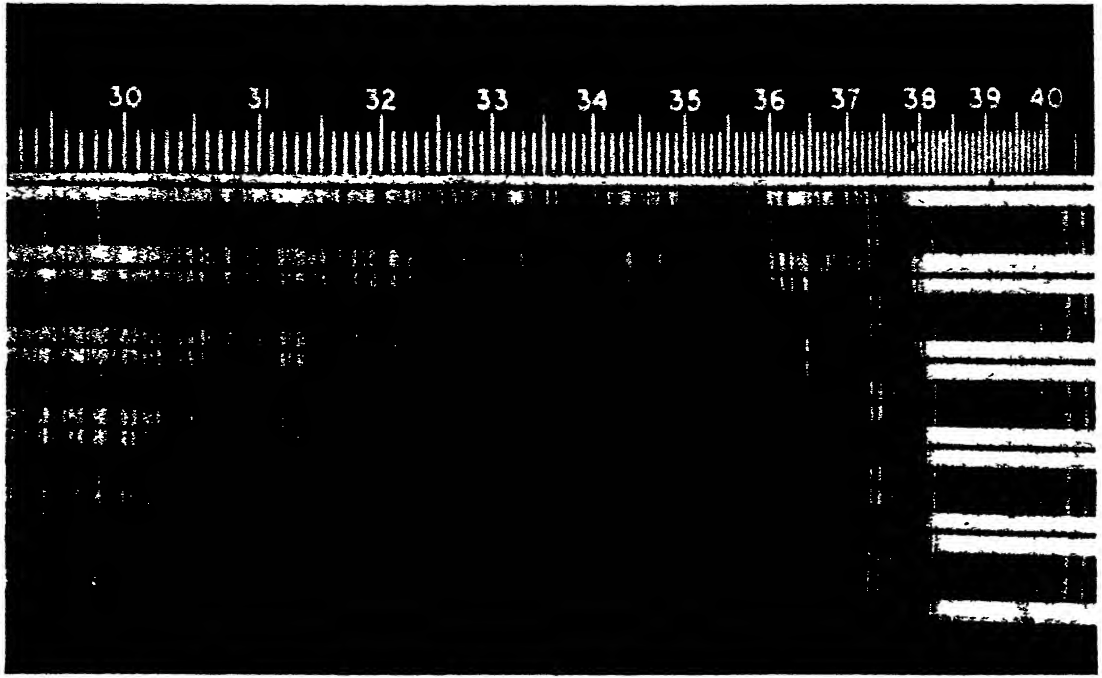


PLATE C.

ENLARGED PORTION OF SPECIOGRAM SHOWING ABSORPTION OF ANTHRACENE IN ALCOHOL, OBTAINED WITH NOTCHED ECHELON CELL OUTFIT AND HILGER QUARTZ SPECIOGRAPH, E3

means of a single exposure lasting less than a minute, that it is equivalent (as regards the information it will yield) to ten exposures with any other type of spectrophotometer, and that these ten equivalent exposures would probably take at least 20 minutes to obtain. A further noteworthy feature of the method is its economy as regards the amount of solution required—the capacity of each cell being only 0·4 c.c.

Once the spectrogram is obtained the procedure is exactly the same as with, for instance, the sector photometer. The

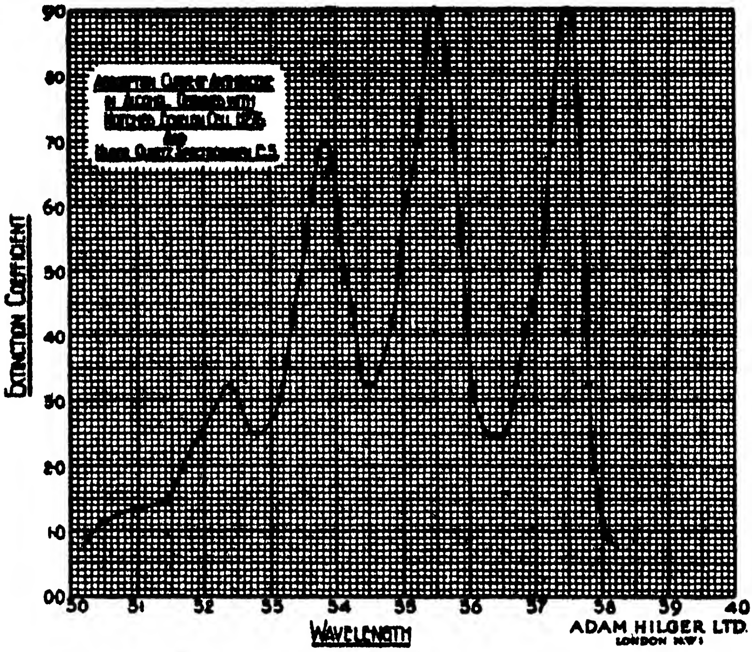


Fig. 3.—Absorption curve of anthracene in alcohol plotted from spectogram shown (Plate C).

points of equal intensity in each pair of spectra are noted, and, since the reduction in intensity of the comparison beam due to the rotating sector is accurately known, the density of each individual column of liquid is obtained. Knowing the density of a column of known length, the extinction coefficient for the wavelength in question is immediately deducible, and the curve of extinction coefficient against wavelength can be drawn. Fig. 3 is the curve obtained from the spectrogram reproduced.

Miller [10] has also attempted to devise a method whereby the necessity for taking a large number of separate photographs is obviated, and he has succeeded in cutting down the number of exposures to two. A source of light casts an image upon the

spectrograph slit by means of an achromatic lens. Between the slit and the spherical lens are introduced two cylindrical lenses, the axis of the lens in each case being horizontal. One

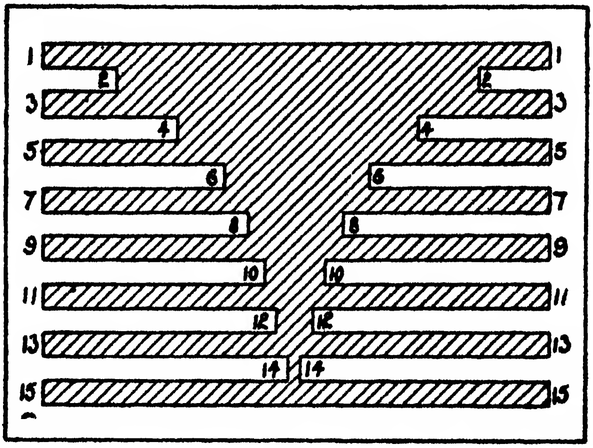


FIG. 4*a*.

of these cylindrical lenses is placed close to the slit and acts as a field lens to prevent light being lost in passing through the spectrograph. The other cylindrical lens produces an image of

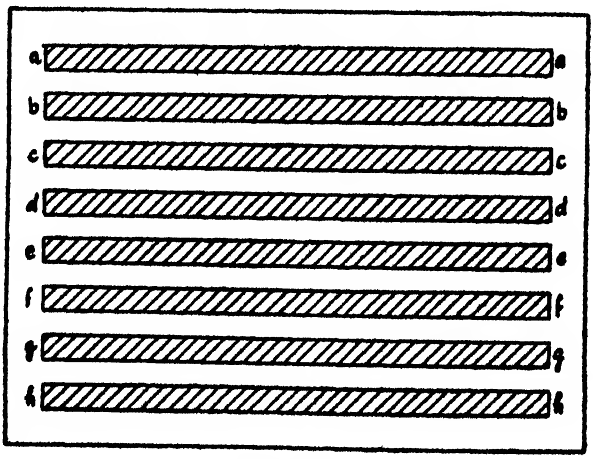


FIG. 4*b*.

a diaphragm (such as that shown in Fig. 4*a*) on the slit. This diaphragm is placed close to the slit side of the spherical lens.

The result of using such an optical system is that on the photographic plate there will appear a series of spectra, one for each aperture in the diaphragm, and the intensity of each

spectrum will be proportional to the length of the corresponding aperture. Thus the intensity of the spectrum corresponding to the strip 11 will be proportional to the length 11, and since 11, 33, 55, etc., are all equal in length, it follows that the spectra corresponding to these strips will be equal in intensity. The intermediate areas will show diminishing intensities, however, proportional to the lengths 22, 44, 66, etc. Behind this diaphragm can be placed a second diaphragm (4*b*) whose openings are identical in size and position with those of the 11, 33, etc., openings of the first aperture.

Two spectrograms are now taken. The first is through a dummy cell containing, say, the solvent employed. The two diaphragms are so arranged that light only passes through the spaces 22, 44, etc. The spectra registered on the plate are thus each reduced in intensity to an extent of which the varying lengths 22, 44, etc., are a measure. Obviously this is equivalent to passing each of the beams through a known density. A second exposure is then made with a cell containing the liquid under study in the beam and with the apertures in the second diaphragm opposite the 11, 33, etc., apertures of the first one.

Consideration will show that the final photograph, although it resembles both that given by the sector photometer and that by the notched echelon cell, is only really comparable to the sector photometer type. The echelon cell possesses the advantage that the matching between pairs of spectra in any one composite spectrogram always takes place at the same intensity, that of the beam passing through the rotating sector. This is a decided advantage in that it involves all the "matchings" taking place under identical conditions on the same region of the characteristic curve of the photographic plate employed. Neither the photometer just described nor the sector photometer possesses this advantage; every match point in the series of comparisons is observed at a different point of the characteristic curve, and errors may well creep in here. A further disadvantage is that the exposure required is that necessary to obtain a satisfactory blackening of the photographic plate with the full length of liquid (which is constant) in the region of highest extinction coefficient; whereas in the echelon cell the photograph of the region of high extinction coefficient is taken through the shortest length of liquid, this latter procedure obviously being preferable when speed is in question.

A much more serious disadvantage, however, is the fact that the absorption and comparison spectra are not obtained simultaneously, and that it is necessary to assume that the two separate exposures are identical. Very serious errors may be incurred here due to fluctuations in the light source, this being particularly the case where short exposures are in question.

It is not known whether Miller's photometer has actually got past the suggestion stage as yet, but it is of interest as being quite a distinct line of approach to the problem.

O'Brien [11] has also suggested another line of attack which, so far as may be judged from the few details available, does not suffer from the disadvantage that two independent exposures are necessary; as with the notched echelon cell a single exposure gives the composite spectrogram from which the absorption curve of the substance in question is plotted. A toothed mirror is set up in front of the spectrograph slit and two beams from the same source of light are brought to the slit, one beam after passage through the spaces between the teeth, the other beam after reflection from the teeth themselves. The first beam is acted upon by a logarithmic sector (see SCIENCE PROGRESS, p. 293, October 1932), so that the intensity of the image along the slit varies. The second beam passes through a column of the liquid under examination. Again, a composite spectrogram is obtained which is comparable to that obtained with the sector photometer, and which is not truly comparable to the echelon cell spectrogram for the same reason as was cited against Miller's scheme.

The use of a mirror for the diverting of one beam is a very serious flaw in the scheme, since the reflecting power of any mirror varies with the wavelength. This, however, could be overcome by the substitution for the mirror of a Lummer-Brodhun cube.

Sufficient has been said to show that the problem of the rapid determination of the absorption data of liquids is engaging a considerable amount of attention, and that already one successful solution has been obtained. The problem is of undoubted importance, since any method which will permit of absorption data being obtained almost instantaneously will render possible the study of substances whose constitution is changing rapidly, and would make it possible to follow the course of many reactions. Such an achievement should be of great use in the study of biological and similar fluids.

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SIR JOHN LESLIE (1766–1832)

By H. G. WAYLING, M.Sc.

THE late Andrew Carnegie is reported to have said that the best thing that can happen to a Scottish boy is to be born poor. Certain it is that the subject of this sketch was not handicapped at his birth with a load of this world's riches. He was born at the fishing town of Largo in Fifeshire, where Alexander Selkirk, the prototype of Robinson Crusoe, also first saw the light. Leslie's father was a carpenter and John was the youngest of the family. His early education he received in his native town, with supplementary help in mathematics from an elder brother. It appears that Leslie's exceptional abilities showed themselves prematurely, and evidences of his mental achievements were brought to the notice of Prof. John Robison, of Edinburgh University, who before his removal from Glasgow had been an admiring friend of James Watt. At Robison's suggestion it was urged upon the Leslie family to strain their slender resources and send John to St. Andrews University, that being the nearest and least expensive when travel and lodgings were taken into account. So, in his thirteenth year, the future natural philosopher became an undergraduate, hoping, by sustained application to his studies, to repay some day the sacrifice his parents were making to give him an academic training. Fortunately the struggle ceased after his first term. The Chancellor of the University, the eighth Earl of Kinnoull, became acquainted with the youthful prodigy, and volunteered to pay the boy's expenses provided that he gave an undertaking to enter the Church at the end of his college career. As the future for John was as yet undefined, one calling was as good as another when the immediate prospects were so favourable. Consequently it was decided that as a theological student he should stay at St. Andrews for five years.

It is doubtful whether Leslie ever felt himself divinely called for the profession earmarked by his patron, since, when he left " the royal and ancient city " for further study at Edinburgh University, and came in contact with the experimental teaching then booming at the Scottish capital, he realised that his natural bent inclined more to science than to divinity. As the Earl of Kinnoull died during Leslie's studentship at Edinburgh, he

felt under no obligation further to continue his preparation for the ministry, and decided to concentrate wholly on natural philosophy. This step may have been hastened by his companionship with a fellow student, James Ivory, with whom he shared rooms. Ivory's theorem perpetuates the name of a mathematical genius, and the Royal Society of London added distinction to its author by awarding him a Royal medal in 1814 for "Various Mathematical Contributions to the Philosophical Transactions." With such a brilliant acquaintance, Leslie's own talent was stimulated and developed and, later on, while he occupied the Chair of Mathematics at Edinburgh, Ivory was professor of the same subject at Marlow Royal Engineering College. Before he finished his student days, Leslie was becoming a person of some note. He directed the studies of a nephew of Adam Smith and also made the acquaintance of Tom Wedgwood, the youngest son of the famous potter. Wedgwood had gone to Edinburgh to join his elder brother Josiah, to whom the northern capital was as much a resort of pleasure as a place of learning. Leslie and Tom—who was the younger of the two by five years—corresponded at intervals after they left the University in 1787; Wedgwood enjoying the amenities of the countryside at his father's mansion, Etruria Hall, Staffordshire, while Leslie was working at a precarious livelihood as coach and scribe. Between 1788 and 1790, he accepted a post as tutor to an American who had studied at Edinburgh, and left Scotland to reside in Virginia. His opinion of the New World probably coincided with that of Priestley. Where one had looked for civic toleration in the land of liberty, only a spurious substitute was to be found, for when Tom Wedgwood contemplated a voyage to America in 1793, Leslie dissuaded his friend from embarking on such an unpropitious holiday. On his return from America, Leslie lived in London for a while. He wrote articles for the *Monthly Review* and compiled notes on the Bible for a publication edited by a Dr. Thompson. So far Fortune had not been immoderately kind to the aspiring scholar; but now she was to lead his steps into pleasant places, and for a time it was to be "roses, roses all the way."

A call came from Tom Wedgwood, whose fondness for science had every encouragement in his father's private laboratory. This young and rather frail philosopher suggested to his father that Leslie should come to Etruria as tutor to himself and his brother Josiah. What an ideal proposition and what fruitful prospects! The indulgent father agreed, and Leslie, overjoyed at such an unexpected turn of good fortune, took up his duties as guide, philosopher, and friend on the best of terms with his pupils and himself. From 1790 to 1792 the Wedgwood household became engaged in more experiments

SIR JOHN LESLIE

From Jerdan's *National Portrait Gallery of the Nineteenth Century* [Fisher].

than ever. The head of the family had published several papers on topics allied to the pottery industry in the *Philosophical Transactions of the Royal Society*, and the disposition for research in high-temperature ceramics descended from father to son. Before Leslie left Etruria, Tom Wedgwood had sent a communication to the Royal Society, entitled "On Emission of Light from Heated Bodies." No doubt the Scottish tutor witnessed these labours, even if he did not actually participate in them. In this research, silver cylinders, one blackened and the other polished, were fixed in the ends of earthenware tubes and roasted intensely together in a crucible. The darkened rod began to shine a considerable time before the polished one and remained somewhat brighter throughout the firing. When, however, they were partially withdrawn from the furnace a reversal of luminosity occurred, and the blackened cylinder turned the duller. Wedgwood in further investigations used blackened and polished canisters. It is therefore not beyond the realms of possibility that these results set Leslie pondering, and his own classical researches in radiant heat took their origin in Wedgwood's experimental workshop. While pupils were busy with their crucibles, Leslie was writing on Theories of Electricity. He demonstrated that a heated thermometer cools quicker when electrified than when in a neutral state, since streams of electrified air from the former would carry away heat the more rapidly.

Another side of his busy mind found occupation in this rural retreat. He translated for a London bookseller Buffon's massive work on the *History of Birds*, for which he was sufficiently well remunerated to pursue at Largo his researches on radiant heat after he had left the service of the Wedgwoods. His departure from Staffordshire was not in the nature of a dismissal. The indifferent health of Tom Wedgwood was always a matter of concern to the family and, in the hopes of effecting some amelioration of his ill health, a voyage to America was contemplated. In order also that all means might be taken to obtain as complete rest as possible and to be free and unfettered in his search for convalescence, Tom severed his partnership with the firm. Instead, however, of crossing the Atlantic, Wedgwood took Leslie with him to Holland. From now onwards, the two companions indulged in foreign travel until Tom died in 1805. Thenceforward, Leslie generally included a visit to the Continent in each year's itinerary. This complete change of scene must have reacted favourably on Leslie's occupation of author and tutor in his native county, precarious though it might have been. As early as 1787, when only twenty-one years old, he had shown proof of his maturer mathematical powers in an article, "On the Resolution of

Intermediate Problems," which Prof. Playfair communicated to the Royal Society of Edinburgh. The professor was proud of his young pupil, as events afterwards showed, for, when Playfair vacated his chair of mathematics, he ardently supported Leslie's candidature for the post, which led in no small measure to the desired appointment. Playfair's status as mathematician, author, and lecturer was of an international character. He served on a national committee with Wollaston, when the length of the second's pendulum was fixed in terms of the standard yard; and his reputation as an author of choice and lucid prose was so renowned that, according to his collateral namesake, Dr. Lyon Playfair, the professor hardly ever ventured to make a speech in public for fear of damaging his literary fame by any accidental departure from his perfect linguistic style.

Among Playfair's English acquaintances was the Rev. Nevil Maskelyne, the Astronomer Royal, who entertained the Scottish professor whenever change of scene or scientific business brought him to London. Their friendship began in 1774, when Maskelyne was estimating the relative density of the earth by observing deviations of the plumb-line near Schiehallion in Perthshire. Partly to satisfy curiosity and partly to welcome the English astronomer during his sojourn in Scotland, Playfair and other local scientists paid their compliments to Maskelyne and even shared occasionally in his labours.

Therefore whenever a brother Scot desired letters of introduction to the scientific society of London, Playfair usually appealed to Maskelyne to act as host and cicerone. In 1794 Leslie came to London as Maskelyne's guest, and dined at the Crown and Anchor in the Strand at one of the monthly dinners of the Royal Society Club. Thirteen years later, when Professor of Mathematics at Edinburgh University, he enjoyed the same hospitality, with David Brewster as his companion. He was roving abroad again in 1796 with Tom Wedgwood. The good companions travelled through Germany and Switzerland and met Thomas Young at Göttingen, where the English prodigy was then a student. The trio explored the Harz together, and from this chance meeting, Young seemed thereafter to follow Leslie's researches and publications with the interested if slightly critical eye of a reviewer. Leslie during this trip took the temperature of springs and wells to see if the readings represented the mean temperature of latitude at different elevations above sea-level. His observations were found to be generally in accordance with what he had theoretically anticipated. It was about this time that Tom Wedgwood granted his needy friend an annuity of £150, to be increased in the event of Leslie marrying. The gift was made with the aim of

putting him in a position to continue working at physical science unhampered by anxiety as to his daily bread.

Leslie was now thirty years old. He had been pursuing his experimental enquiries, but had not got any post suitable to his powers, or any other prospect of making a regular income. His friend was solicitous that the gift should " materially increase the sum total of Leslie's philosophical product." Such generosity naturally received most cordial thanks, which the recipient expressed in a letter of ornate magniloquence. Thus assured of a fair competence, the befriended Scot wrote and laboured with such vigour, that at the turn of the century he had planned and nearly completed a scientific superstructure of substantial proportions. With age and success came daring. Leslie the bachelor, who worked as he willed and played when he pleased, was not without his amorous adventures. His stay at Etruria, in a household whose family included three charming and cultured young ladies, had set his heart beating and his imaginative mind aspiring that some day his love-dreams might be realised. Now, with increased years and courage, he commissioned Cupid to speed a trial shaft. From Islington he wrote a letter to young Wedgwood in which he tentatively enquired whether he could hope for the hand of one of Tom's sisters. The reply gave him no hope or encouragement and the matter was never referred to again.

This unsuccessful love affair, however, did not abate his ardour for scientific pursuits. Two years after, in 1802, he published the first correct explanation of the cause of the rise of a liquid in a tube, by considering the effect of the attraction of the solid vessel on the very thin stratum of fluid in contact with it. When his friend James Ivory wrote in the *Encyclopædia Britannica* on the subject of Elevation of Liquids in Tubes, he said, " Reckoning from the present time to speculations of the Florentine Academicians, the formula of La Place and the remarks of Professor Leslie are the only approach that have been made to a sound physical account of the phenomenon." These remarks did not please Thomas Young's biographer, who asserted that Young had attained the same results by resorting to no hypotheses respecting molecular forces but such as were required to produce the mutual actions of the solid and fluid upon each other and to account for the uniform tension of the envelope of the fluid without which the equilibrium could not be maintained.

In 1802 also, Leslie gave a preliminary advertisement of one of his discoveries in radiant heat, namely, that the amount of heat emitted from a hot vessel depended upon the nature of the surface of the receptacle. He went further and said that the transmission took place by pulsations in the ambient air,

propagated with the velocity of sound. These introductory statements were followed in 1804 by the publication of his magnum opus entitled *The Experimental Enquiry into the Nature and Propagation of Heat.* The volume was dedicated to Tom Wedgwood. It embodied the results of the investigations the annuity afforded him to carry on for seven years at his home in Fifeshire. The purpose of his scientific enquiries was to discover the properties of what is termed radiant heat; to examine the heat derived from the irradiation of the sun and to explain its distribution "by the vehicle of atmospheric commerce over the surface of the globe"; and finally, to unfold the mutual affections of air and moisture and exhibit the results of his hygrometer so that he might prepare a solid foundation for a system of meteorology. The book was illustrated by Wilson Lowry, a skilled line engraver well known to Fellows of the Royal Society and to members of the Royal Institution in Albemarle Street. The book caused something of a stir. The originality of his experiments and their surprising results stamped him as a worthy compeer with his other illustrious countrymen—Cullen, Black, and Watt. The Royal Society of London promptly awarded him the Rumford medal, the intrinsic value of which was fifty guineas, and so placed him second in the line of descent to Count Rumford himself, the original donor and pioneer investigator into the nature of heat.

Thomas Young—who ever after the discouraging and erroneous estimate set by certain Scottish critics on his experimental enquiries into the undulatory theory of light and who may have been chary of placing too favourable an assessment on scientific discoveries made north of the border—considered that Leslie's researches on radiation would have been more fruitful had he been less dogmatic in upholding Newton's teaching. This was probably fair comment. Leslie was a fervent admirer of the *Principia*, as we may infer from the fact that this masterpiece was usually one of the prizes awarded to the most meritorious students of his Natural Philosophy class. At times he was not very good at theorising, and formed artificial and faulty theories to explain facts, and he was occasionally sceptical of the genuineness of other men's discoveries, as he refused to recognise William Herschel's discovery of radiations less refrangible than red light, and discounted the results obtained by Wells in his experimental operations on the formation of dew.

Now for a few words about the apparatus he employed in his laboratory. As is fairly common knowledge, they are his cube, his differential thermometer, and his concave mirrors. The four vertical faces of the canister were severally of a different superficial nature, for, as he discovered, the character of the

surface affected the quantity of heat, and of cold, emitted. His mirrors like his cans were of tinned iron, made in sections by hammering them into shape over wooden blocks. They were often parabolic and sufficiently powerful to ignite cloth and wood at the focus. However, it is the differential thermometer that Leslie exploited to the full. If he did not invent it —an honour ascribed to Sturmius and Altdorf—yet, with practically the same essential parts, he employed it, first as a hygrometer, then as a pyroscope, a photometer and subsequently as an æthrioscope. In his hands it was a veritable old man of the sea. This differential thermometer, as most physicists know it, consists of a length of capillary tubing bent into the form of the letter U. It contains a thread of some liquid and has hollow spheres sealed on to the upper ends, so as to possess a continuous bore from bulb to bulb. Leslie covered one of these spheres with a moist cloth coat and used the thermometer in this state to estimate the relative humidity of the room or enclosure in which the hygrometer was placed. It was when the instrument was put under the receiver of an air-pump that he discovered what intense cooling effects the evacuation of the bell jar produced; in fact, the hygrometer led him ultimately to devise a method of obtaining ice by artificial refrigeration, a result that will be referred to later on.

So much for his hygrometer. With its moist cloak removed, it became his differential thermometer. With this he performed a multitude of experiments on radiant heat, by putting one bulb at the focus of a mirror. Again, with one of the glass globes blackened he christened the instrument a photometer and studied the effect of the sun's rays on it at different hours of the day. Alternatively, by covering one sphere only with silver leaf, he adjudged the relative power of heat rays from his kitchen fire at various distances from the source of heat, since the metal-clothed ball reflected the warmth and only the naked one absorbed it. After this one would imagine that he had reached the last of the permutations that could be played on this instrument. But, no. In 1817 he invented another modification which will be described subsequently and which he designated an æthrioscope. Returning now to the researches themselves, not only did he fill his cube with hot water, but also with a freezing mixture; placing, as was customary, one bulb of the differential thermometer at the focus of the mirror. As he now obtained excessive chilling effects, he concluded that cold had as real an objective existence as heat; and was similarly propagated by pulsations through the intervening air. This notion that cold, like heat, was a quantitative entity was accepted fairly generally in his generation, and Leslie's results appeared to confirm such an assumption. By intercepting

glass and metal screens between cube and mirror, he discovered that metals guard the detector bulb from heat or cold more effectively than glass. While he was privately investigating the properties of radiant heat at Largo, Prof. Charles Hope was publicly performing experiments at Edinburgh University in which he demonstrated how it was possible to find the temperature at which water was at its maximum density, and that not at zero as might have been surmised. It is of some interest to note how the subject of heat has been developed and extended by Scottish investigators. We have mentioned Cullen, Black and Watt, Leslie and Hope. But George Fordyce, Adair Crawford, William Ritchie and William Wells in England were contemporary pioneers in their several ways, while John Rutherford, Forbes, Clerk Maxwell and Lord Kelvin were all explorers in the domains of thermal phenomena.

The year following the publication of his classical volume, he was appointed Professor of Mathematics at Edinburgh, in succession to Playfair, who had been installed in the Chair of Natural Philosophy. Brewster's name was also mentioned as a possible rival but not very seriously. An academical contest for the post, however, did take place which split the city into two camps. The lay population mainly championed the claims of Leslie, while the Church rallied to the standard of a challenger named the Rev. Dr. Macknight. The reason for the clerical opposition arose from the fact that Leslie in his recent book had spoken of the unsophisticated notions of mankind about the relations of cause and effect. In this and other remarks the ministers of the Established Church saw the insidious workings of David Hume's gospel of freethought. Playfair's vacant chair might soon become the rostrum for promulgating infidelity camouflaged under the guise of mathematics. The contest kept Edinburgh excited for several weeks. From pulpit and printing press contending arguments flowed copiously forth. Playfair wrote an open letter to advocate Leslie's suitability for the position. Under the pseudonym of "A Calm Observer" David Brewster issued a pamphlet apparently aiding and abetting the ecclesiastical party, but which on closer reading resolved itself into facetious leg-pulling which set the city tittering. The Town, as we know, won the day, and on March 12, 1805, Leslie was appointed joint Professor of Mathematics with Dr. Adam Ferguson, who had been Playfair's senior colleague. Assured now of a secure livelihood, he took matters more leisurely; for not until 1809 did he publish any other notable effort and then he issued his *Elements of Geometry, Geometrical Analysis and Plane Trigonometry.*

His love of experimentation found expression again, the next year, through further fondling of his hygrometer, which,

as we have remarked previously, was the forerunner of the differential thermometer. In this case he succeeded in freezing water artificially. The remarkable amount of cooling which accompanies rapid evaporation under a vessel exhausted of air was known to earlier experimenters like Nairne and Smeaton, but to Leslie is due the credit of absorbing the superincumbent vapour almost as soon as it is produced, thereby rendering the change of physical state more expeditious and more refrigerative. He placed a saucer of strong vitriolic acid as a companion to a cup of water under the bell-jar of his exhausting engine, and by this means obtained the first sample of ice made at will artificially. Soon afterwards, air pumps were working overtime at the newly discovered process of refrigeration. Of course this revelation of another of Nature's secrets established his reputation as an experimentalist of premier rank. Wollaston in London modified the method of producing ice by the invention of his cryophorus. This is shaped somewhat on the lines of Leslie's differential thermometer, the bulbs being at each end of a straight glass tube. It is not so automatic as its prototype, as an external freezing mixture is essential to bring about congelation inside the instrument.

From 1796 up to the year 1812, Leslie must have felt financially contented. He had a professional remuneration as well as an annuity from the Wedgwood family, which had been generously continued seven years after the death of their youngest son. He was still a bachelor, enjoying his continental visits from year to year, and during session time freely mixing in the best society of Edinburgh. Contemporaneous with his publication of the art of making ice, he composed a work on the Geometry of Curve Lines. Being now able to measure his mental stature against any other professional personality of the north, his sovereignty in the realm of radiant heat may have inclined him to discount the labours of others who appeared to be intruding on his preserve. Already it has been stated, he discredited the discoveries of Herschel on infra-red rays. Another instance of his disbelief cropped up again in 1814 when Dr. Wells published an account of his investigations on the formation of dew, with accompanying inferences on his practical observations. Wells came of Scottish parents and was born in South Carolina. He received part of his education at Edinburgh University and part in London. His experiments were conducted mostly in the suburbs of the metropolis, but a few of them were performed at his lodgings in Fleet Street. A mural tablet to his memory is in St. Bride's Church, close to Ludgate Circus. His investigations were thoroughly done and most of his conclusions are still accepted. The Royal Society recognised his contribution to the science of heat by awarding him

the Rumford medal as it had done ten years earlier in Leslie's case.

It was proved by Wells that dew formed locally on those substances which became cooler than the surrounding air and that ground temperatures were often much below those prevailing a few feet higher up. Leslie rejected these explanations and affirmed that a continual darting of cold particles from an azure sky by day and by night caused the deposition of dewy moisture. This theory was in keeping with his own experimental results from which he formulated that his cold canister shot out its chilling pulses into the focal bulb of the differential thermometer. Wells, in refuting this assumption that cold pulsations from the higher strata of the atmosphere descend, pointed out that if this were the case, "a less cold ought to be found on a clear still night in the lower than in the higher strata, which is contrary to the uniform observations of Pictet and Six." How enamoured of a scientific achievement an investigator may become is well illustrated in Leslie's devotion to his differential comparator. His discoveries with its aid had brought him eminence in his particular profession. It was natural then that he would visualise its usefulness in some form or other wherever he looked. It is said that both Archimedes and John Bernoulli desired their respective spirals to be cut on their tombstones, to testify to their mathematical discoveries; while it is a fact that Rowlands of Johns Hopkins University was buried beneath his dividing engine. If Leslie had ever expressed a desire to be posthumously remembered, his differential thermometer would surely have figured on his gravestone or accompanied him to his last resting-place.

Under the name of Æthrioscope he modified his favourite apparatus, giving it three distinct forms called respectively erect, sectoral, and pendent. Briefly, mirrors partly encompassed the bulbs instead of being used apart. These instruments he found so sensitive that the liquid index rose and fell with every passing cloud. In reviewing his main line of research, it is evident that Nature's skin was more interesting to him than her solid flesh. He explained the rise of a liquid in a narrow tube by focusing his attention on the contiguous films of solid and fluid. Was it not the rapid evaporation at the surface of a liquid that achieved the transformation of water into ice? Nature like Beauty is skin deep. Further, he could fundamentally change the radiating powers of a solid simply by painting, polishing, or powdering its surface. In the open air, ploughed land and meadow, sandy beach or rocky crag were just experimental areas on the bosom of Mother Earth that variously moved the liquid lymph in the gland of his differential pulsometer. To him it was the moon's veil rather than her

volcanic subsoil that gave fair Cynthia her silver beauty. The light reflected from our satellite owes its splendour to the nature of its superficial vesture, which he declared was phosphorescent like the Bologna stone. During his stay in Paris in 1814 he told Arago his conjectures, which drew from the French savant the interesting comment that moonbeams must be reflected sunlight since they contain polarised rays. Behold, then, another tribute to the wonder-working properties of a surface. It should be observed that most of his experimental labours in Natural Philosophy were carried out while he was Professor of Mathematics. Occasionally he lectured for Playfair when the latter was engaged on Royal Commissions or was in ill health, and a deputy for the Natural Philosophy classes was required.

Thus it seems that experimental enquiry was his chief predilection. Never for very long did he set aside his scientific instruments, and his beloved hygrometer seemed always in his thoughts. An interesting return to his first love occurred in 1817, when this instrument was reconditioned again for research. He found it was possible to obtain very low temperatures as before, induced by the rapid evaporation of water, but in this instance promoted by the presence of certain desiccated powders and not by oil of vitriol, as in previous experiences. The power of most fibrous material and of crumbled solids to become damp and absorb moisture inordinately is a matter of common knowledge. A fortune has been made by manufacturing a table salt that keeps permanently dry, and another might possibly be amassed if bedclothes that needed no airing could be woven. Leslie collected some " shivery " fragments of porphyritic " trap " that littered a local pathway, and first grinding them and then thoroughly roasting them before his kitchen fire, he dropped the dry particles into a clean wine decanter and quickly replaced the stopper. Hurrying from home to college with his newly prepared desiccating agent —Playfair was away in Italy at the time and Leslie was deputising for him—he placed the unsealed decanter and a dish of water under the bell-jar of his air pump and had the satisfaction of demonstrating to his expectant pupils how ice could be made in this novel way.

When Playfair died in 1819 there was only one person who could rightly claim to be his successor, and that of course was John Leslie, and for a second time the mantle of Playfair fell on him. A further honour came unsolicited in 1820 when he was elected a corresponding member of the Institute of France, a compliment of which he was pardonably proud. Leslie did not succeed very well as a lecturer, possibly because he assumed too high a mental standard on the part of his

auditors, as Thomas Young at the Royal Institution had done. As a manipulator, however, he was skilled and resourceful, his class giving him more support for what he performed than for what he expounded. Mrs. Mary Somerville in her Memoirs has given as clear a portrait of him as anyone. She writes:

"We became acquainted with Prof. Leslie and liked him. He was a man of original genius, full of information on a variety of subjects, agreeable in conversation and good natured, but with a singular vanity as to personal appearance. Though one of the coarsest-looking men I ever knew, he talked so much of polish and refinement that it tempted Mr. William Clerk (who by the way was in the same family tree as Clerk Maxwell) to make a very clever clay model of his ungainly figure. The professor's hair was grey and he dyed it with something that made it purple, and as at that time the art was not brought to its present perfection, the operation was tedious and only employed at intervals, so that the professor's hair was often white at the roots and dark purple at the extremities. He was always falling in love and made me his decoy duck, inviting me to see some experiments, which he performed dexterously; at the same time telling me to bring as many young ladies as I chose. He was unfortunate in his aspirations and remained a bachelor to the end of his life."

Among those whom he hoped would flatter him by their presence was charming Miss Kerr, the daughter and heiress of Charles Kerr, Esquire, of Kelso, who was possessed of a considerable fortune. Rumour said that Playfair also was a candidate for the hand of this fascinating young lady, who, however, as the widow Mrs. Apreece, married Sir Humphry Davy.

After his appointment to the Chair of Natural Philosophy, there was only one incident of note that disturbed the even tenor of his way. The form of his latest invention, the æthrioscope, had been anticipated by Wollaston, who had described its construction and sensitivity to Biot. The Frenchman published an account of the instrument in the journal which he edited, and although Leslie denied all knowledge of Wollaston's priority, certain insinuations of plagiarism streamed into circulation. The matter came to a head in 1822, when *Blackwood's Magazine* openly charged him with claiming other men's inventions as his own. Leslie instituted proceedings against the proprietors for this libel and obtained a verdict of £100 damages.

From now onwards he appears to have rested on his oars. He had completed his jubilee, attained an exalted position in his profession and just taught or travelled as duty or convalescence demanded. James David Forbes, who was a youthful member of his class, said, "Leslie, though now somewhat past

his prime, still gave instruction in Natural Philosophy at Edinburgh University." This was the class in which was handled all those subjects on which Forbes had dwelt almost from his tenth year. This young philosopher, who carried off prize after prize, succeeded Leslie when he died in 1832. He was on friendly terms with his professor, "as friendly as the latter's singular nature would allow," and had frequent though slight proofs of his master's good opinion. When Forbes thought of entering on a legal career, Leslie dissuaded him from that course, intimating that he had Forbes in mind to take his lectures when he travelled in the Near East. In the last year of his life, Leslie was knighted at the recommendation of Lord Brougham. He died at Coates a short distance from his native town. James David Forbes, who showed that radiant heat can be polarised and whose thermal conductivity bars have been for so long familiar apparatus in physical laboratories, was appointed to succeed Leslie, at the early age of twenty-three years.

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ESSAY

THE "BIBLIOTHÈQUE SCIENTIFIQUE DE L'INGÉNIEUR ET DU PHYSICIEN" OF PROFESSOR H. BOUASSE (G. F. Herrenden Harker, M.A., University College, Cardiff)

THERE appears to be three ways of writing a comprehensive treatise on Physics.

The first is the English way. This consists in starting out with the best of intentions by a prefatory announcement to the effect that "the volume now presented must be regarded as the opening one of a series forming a textbook on Physics," and then defaulting more or less rapidly and gracefully. We may be informed long years after that "the intention of proceeding with the other volumes is now definitely abandoned." We may be left hoping indefinitely for the completion of the work . . . if our experience of the volumes actually in existence has left us any grounds for hope. Failure to fulfil the contract may perhaps be attributed to the fact that such attempts have usually been a dual concern, in which the partners do not seem to have worked smoothly in collaboration. In any case the disadvantages of this particular method are too obvious to need stressing.

The second is the German way. This consists in an editor, or a group of editors, drawing up a skeleton programme, and then subletting the clothing work among their friends. There was a time when this subletting was apportioned in stretches of substantial length, for instance, by confiding one branch of the subject to a single authority. Unfortunately it now appears to be approaching its logical terminus in which chapters are, and perhaps even paragraphs will be, handed over to individual specialists. That this is no fanciful exaggeration can be verified by a glance through the prospectus of any contemporary "Handbuch." The sole advantage of this method would appear to be that it constitutes a substantial guarantee of reasonable promptness in publication. Its drawbacks, though perhaps not so brutally obvious, are most emphatically real. A work conceived on such a plan must inevitably lack unity in execution, if not in design. An expert, for all his learning in minutiæ, may lack wisdom in essentials, and

to treat his contribution, which is virtually a technical pamphlet on a circumscribed topic, as a potential chapter or section in a treatise on Physics is to entertain a singular conception of the true nature of such a treatise. To exhibit a question in its proper perspective is, not to compose a monograph on it, but to situate it in an ensemble, to locate it against a background. In so far as our knowledge permits us to judge, it would seem that different questions have a very diverse importance. The narrow specialist almost invariably adopts a false scale of values ; it is in his own interest to magnify the significance of the particular work upon which his reputation rests, and which he naturally tends to equate to the universe. It is a fallacy to imagine that a bundle of essays of such a nature can be welded into an organic unity by the simple expedient of encasing them within the same binding cover. Intellectual co-operation of this sort can never adequately replace the vision and insight of the individual thinker, or the cumulative value of his labours.

There remains, however, a third way. This is the French way, as exemplified for our present purpose by Professor Henri Bouasse of Toulouse. It is that of a single mind essaying, and achieving, the stupendous task of reviewing, rethinking and consolidating the present-day position in classical Physics, and its allied subjects, on a preconceived and carefully executed plan. To string together a compilation requires only the pedestrian talents of patience and perseverance. To write a great treatise is an undertaking of an entirely different order of magnitude. The French outlook is characterised so pre-eminently by clarity allied to logic, by profundity untainted by pedantry, that the French rank supreme as writers of textbooks. Bouasse's work is in the purest French tradition, than which there could be no higher praise.

That a person's chief claim to fame should be a collection of textbooks is liable to cause superior people to sneer. It has become fashionable to despise the man who writes a textbook as compared with the man who turns out a paper. Searle expressed this attitude concisely in the remark: "If you compose a paper on the nucleus in health and disease you are looked up to admiringly as a hero, but if you write a textbook you are looked down upon condescendingly as a teacher." This tendency to establish a hierarchy between various intellectual activities is to be deprecated. The only vital point is one's eminence in one's particular sphere of activity. Actually it is rarer to encounter true distinction in a text than in a paper, precisely because the former demands the sweep of vision associated with the extensive mind, while the latter can be creditably accomplished on the narrowness of outlook characteristic of the intensive mind. Publication of any sort being a species of self-

advertisement, it is, of course, understandable why the majority should aim at securing this on the easiest terms.

It was towards the year 1900 that the project of writing a comprehensive treatise on Physics first took shape in Bouasse's mind. For thirty years he has devoted himself entirely to the realisation of this aim, with that tenacity of purpose and continuity in effort which is the essence of success. A facility in arithmetic is all that is needed to reckon up the number of hours contained in thirty years, say of three hundred working days each of ten hours' duration, but, as scientific activity is not to be reckoned by the hour like the price of a taxi, it is by no means so easy to appreciate the immensity of the labour that this time represents. The secret of the vitality of his work is his inflexible rule to consult nothing but original sources of information, and never to take facts or opinions from second-hand sources. The latter are all too frequently second-rate sources, perpetrated with scissors and paste pot, and pilferings from texts already in existence. It is excessively difficult to take a scientific paper, to exhibit its worth, to situate it in its proper relation to its surroundings, and to explain how and why it has constituted an advance. For this, it needs more than a specialist—it needs an intelligent man. Although the results utilised are for the most part those of others, Bouasse converts them into permanent possessions before assigning a scheme of values to them, and committing them to paper. He is no mere mental fluxmeter of other authorities, no retail distributor of the ideas of others. Even the dictates of the highest authorities are subjected to scrutiny before acceptance, and nearly all the phenomena described have been reproduced in his laboratory either by himself or his assistants. To weigh evidence in this fashion demands a high intuitive perception and a developed critical faculty. To unite it into an orderly and embracing presentation demands a finely balanced and constructive mind. Bouasse has a cordial detestation of vagueness, pomposity, prolixity, and other species of intellectual poison. In none of his work is to be found any trace of that portentous gravity and impressive incomprehensibility which are often regarded as attributes peculiar to higher scientific work. As he desires above all else to be read and understood, he strives to divest his writings of all vestige of academical pedantry.

The first edition of Bouasse's *Cours de Physique* was published between the years 1907 and 1909. This preliminary venture, in six volumes and just over two thousand pages of text, was advertised as conforming with the programmes for the Certificat and Agrégation in Physics. Certain carping critics objected that it was not in strict conformity with the sacrosanct programmes and, in particular, tended to overstep their boun-

daries. Bouasse hastened to make amends by withdrawing all suggestion of acting as an examination chauffeur from his subsequent work.

In 1910 and 1912 appeared two volumes on Mechanics, which represent a sixfold expansion of Volume I of the first edition. The same guiding principles remain in evidence, but are given a more systematic and less timorous presentation. In the course of his introductory remarks Bouasse says: "Mechanics is an experimental science. It does not consist in the manipulation of formulæ, and it ought to be learnt in a laboratory. The higher teaching of Mechanics does not consist in criticising its principles : these have no validity except in so far as their logical consequences square with experimental findings. Neither does it consist in dishing up so-called 'demonstrations' of these principles, nor in taking your head between your hands and asking yourself, in anguish of mind, if conceivably they might not be true. All this pseudo-philosophy is rank nonsense. It bores students, distorts their outlook, and diverts them from matters of genuine importance. If Newton had occupied his spare moments dreaming about space and time we should not have had the Principia. Higher teaching in Mechanics consists, then, not in meditations as to whether the confines of the universe are plane or curved, but in looking round one and explaining to one's students what one has seen and what there is to be seen. No branch of Physical Science concerns us so directly, or has applications which fall more naturally under our daily observation. We are not all required to operate an X-ray tube, but every day we experiment with the effects of friction, if only in preventing our armchair from escaping beneath us. Elasticity, hydrostatics, hydrodynamics, and acoustics, considered as pure experimental sciences, have virtually disappeared from University programmes. Yet it is more genuinely educative for our future schoolmasters to know those branches of Physics which apply to boats, aeroplanes, pianos, organs, and building structures than to acquire information concerning the ions large and small created by radium. The scientific frame of mind is developed in the younger generation by training them to examine intelligently what they find around them, rather than in describing what it is probable they will never encounter. Higher instruction in Mechanics consists precisely in mustering together all the facts of common experience, and deducing them from a limited number of principles. The things most frequently met with, such as tops, billiards, and bicycles are neither the easiest to understand nor the least interesting to investigate."

Publication of the current, and more or less definitive, edition of the treatise on Physics occupied the interval from

1911 to 1932, and must assuredly rank as the greatest effort of co-ordination ever undertaken by any single man in Physics. This Scientific Library of the Engineer and Physicist, to give it the title Bouasse selected for it, comprises forty-five volumes in octavo format, containing over twenty thousand pages of text, not including some nine hundred pages of preface and nearly six hundred pages of index. To compose and see through the press forty-five volumes of technical material, averaging four hundred and fifty pages apiece, in the space of twenty years is no light task. Even on the kilogram basis it constitutes a staggering achievement. It represents a far more impressive performance when detailed examination reveals its unique qualities.

Each volume of this edition is preceded by a preface, extending to between twenty and thirty pages, written in the vivid and virile style peculiar to its author. The special value of these prefaces lies in the fact that, in them, Bouasse airs with complete frankness his views on the nature and teaching of Physics, the idiosyncrasies peculiar to physicists and mathematicians, and a host of related topics of general scientific purport. It would be only reasonable to anticipate that anyone possessing so fine a sense of proportion would be liberally endowed with that most precious of human attributes—a sense of humour. One is emphatically not disappointed, for flashes of a very subtle humour leaven alike the prefaces and the texts. There are occasions when his humour assumes a militant quality, and merges into satire. This, however, is invariably purposive, rarely bitter, and never malicious, for, as his assistant charmingly phrased it, " when he holds the whip in his hand, he has a smile on his lips." The French handle irony, whether of the light or withering type, as no other nation can. The nearest home products are the prefaces of Shaw, but, whereas Shaw normally leaves us with the problems created by his devastating analysis on our hands, Bouasse provides us with a synthesis as a pendant to his analysis. For, if his prefaces constitute inimitable examples of what Gilbert called the principle of reform by ridicule, the accompanying texts are equally admirable instances of the principle of reform by practice.

The first two volumes of this collection contain the Mathematics used in the succeeding volumes. This is collected together at the outset on the ground that it is easier for the student to acquire, by a proper preliminary effort, the requisite quantity of the right type of mathematics than to try to muddle along without it, or pick it up *en route*. The physicist and engineer view Mathematics in the light of a mechanical procedure of deduction. They have need of an extensive mathematical equipment, but of a strictly utilitarian order. The

physicist is intent upon finding a physical significance in mathematical processes, and is not content to let equations lead him by the nose. He is not interested in formulæ as such, but in what they represent. He does not shun numerical computation as irrelevant, but employs adequate means to obtain a correct result with the decimal point situated properly. Without making any attempt to overwhelm the Physics student with rigour of the *rigor mortis* variety, or to overawe him with generalisations of all-embracing scope, Bouasse does insist on the importance of applicable Mathematics, and its practical laboratory study.

One at least of the prefaces to the six volumes comprised in the section devoted to Mechanics may be singled out for special mention. This is the "Defence of Prefaces," which precedes the volume on Gyroscopes and Projectiles, and which constitutes a spirited vindication of this particular feature of his work.

The next volume, dealing with the Theory of Elasticity and Resistance of Materials is of special interest in view of Bouasse's own early researches. Its preface treats of "the futility of Mathematics for the development of the mind."

The next group of eight volumes is devoted to the study of Fluids. In the preparation of the two volumes dealing with Vortex Motion, Bouasse had the experimental collaboration of MM. Fouché and Marty, rendered imperative on account of the nebulous experimental status of this subject.

Comparatively little of the material contained in the volumes mentioned so far figures in Physics courses as at present laid down in this country. The sections which follow include those portions which are, by convention, admitted here as belonging to Physics.

The first two volumes treat of Thermodynamics, and were among the earliest to be issued in this edition. At the moment they are in process of revision, though the extent of their expansion is as yet uncertain.[1]

The course in Magnetism and Electricity extends to three volumes. In the course of the preface to Volume I, "On certain errors to be avoided in writing a treatise on Physics," Bouasse says: "It used to be deemed an execrable mode of teaching to insert a cortège of notes, references, and quotations in a book destined for students. The method of quoting stray tags of information presents insuperable difficulties. If you are no more than a commonplace compiler, incapable of rethinking the questions you treat, your time would be employed to better advantage in fishing. If you are capable of rethinking

[1] Since the above was written the first volume of the revised and enlarged edition has been published.

a question you cannot help but transform it. Then quotations will strangle you. To quote an authority is, to some extent, to undertake to reproduce his particular viewpoint, which hangs a millstone round your neck." It is not difficult to convey the superficial illusion of learning by listing titles, but it is fairly safe to assume that the more real erudition a scientist possesses the less disposed he will be to make an unnecessary parade of it. Moreover, it is by no means rare to find, among these strings of references which clutter the ground-floor of the pages of so many books, certain inaccuracies and irrelevancies, or even an item which proves, on consultation, to be in flat contradiction with the accompanying text. To the objection that the absence of such references is detrimental to research workers Bouasse adds, "The percentage of our students who are destined to develop into research workers is very small indeed. In any case, it is not altogether undesirable, for such as there may be, to start out by acquiring a rational perspective of the present position in Physics. I feel I can aid research workers more effectively by offering them a reasoned plan than by selling them a catalogue. So many of my colleagues occupy themselves with the latter that I feel no urge to join in the queue. Either Science is a collection of facts without connection like cooking, in which case do not pretend to invest it with any educational significance; or it is a school of reasoning and judgment, in which case you can hardly escape from my insistence on a proper logical lay-out."

The section of the work devoted to Optics includes six volumes, the last two of which were produced in collaboration with the Abbé Carrière, a former student, and the present occupant of the chair in Physics at the Catholic Institute of Toulouse. The experimental verification in connection with the extended treatment of Optical Interference and Diffraction contained in them was carried out by Carrière, who was likewise responsible for the many magnificent illustrations of fringe systems with which they are embellished. The prefaces to both these volumes are noteworthy. The former is a charming disquisition on style, with particular reference to style in scientific writing. The latter, entitled "Advice to Scientists who desire to be read," deserves the earnest attention of all scientific workers embarking on a career likely to involve publication. From it is taken the brief extract which follows:

"Most scientific papers to-day are disproportionately long in view of their meagre content and, judging by the trouble required to disinter what little is of value, they are, moreover, badly drafted. The vast majority purport to report the honest experimental investigations of ordinary persons. We have the right to require that the results of such work, useful but not in

the least epoch-making, should be presented in a rational manner. My criticisms are those of a professor, whose business it is to peruse a large amount of scientific literature. They are not addressed to scientists of genuis, for the peremptory reason that such are invariably the easiest to read. If the investigation of some stray end of some little law has cost you a deal of trouble you must not imagine the result to be measured by the bother it has occasioned you. You are disposed to describe your tribulations and trials which interest us little : it is a story we know because this story is our own.

You tend to follow the fashion by making your début with an historical survey—A has said this, B that, while C upholds a third opinion, and so on. When all the alphabet has been exhausted you have filled a dozen pages, and we are not in the least advanced. I am not anxious to be told about the opinions of A, B, C, and the others; it is a question of you and your experiments. What do you want to show? How are you setting about it?

'But if I don't inform you what these others have found, how will you know about it?'

By reading their papers, which are no more difficult to locate than your own.

'But if my results differ from theirs, ought I not to draw attention to the fact?'

By all means, good Sir, but after you have explained your own results. You put the cart before the horse, more exactly you insert the horse between two carts, because, having started by relating at length the diverse opinions of A, B, C, and the rest, you deign to reveal your own, after which you compare them with those of A, B, C, ——— which ends in consuming some fifty pages, but which sorely tempts me to consign to Hades, you, your opinions, your paper, the opinions of A, B, C, etc., physics and physicists.

Resist the temptation to utilise some perfected registering device after the manner of a skilled artisan. By giving us thirty plates, intelligently chosen, you run no risk of boring us. Why not then provide three hundred? Why not three thousand? Are you a photographer or a scientist? Ah! I begin to understand; you are a candidate for some Academy of Science and must needs have a paper on tap when election time draws near.

After inducing water to traverse a conduit of dimensions $a \times b \times c$, you send it along a series of conduits of dimensions $la \times mb \times nc$, where l, m, and n are anything you fancy. You will have found a steady occupation for life and, of course, you may enlarge the scope of your activities. Modify the section of the conduit. Change it from a rectangle to a triangle, into a circle,

an ellipse, and so forth. At considerable expense substitute in place of water, oil, petrol, and all the organic hosts. Keep on dutifully publishing your results. At the seventy-fifth memoir the Academy will welcome you to its bosom.

From a paper suppress history, idle discussions of apparatus, needless digressions, and pointless tables of numbers. Retain only the precise exposition of the subject of the investigation, the concise description of the apparatus, and the results, condensed into a few graphs or formulæ. Of the fifty or more pages usually occupied there would remain ten which, perhaps, might be worth the trouble of reading."

The two following sections of the work contain respectively four volumes devoted to the study of symmetry and the optics of crystalline media, and an equal number dealing with Electro-optics.

The next main group consists of seven volumes on Acoustics. In the execution of this work, the most exhaustive as well as the best in existence on this particular subject, Bouasse enjoyed the inestimable advantage of the experimental collaboration of M. Fouché, which he acknowledges in the following terms: "To be privileged to meet with a musician (a first-class pianist, an excellent trombone player, and a prizeman in composition) who, in a complex sound composed of anything up to ten non-harmonic partials, can detect them individually without the aid of resonators, and determine their frequencies to within a vibration or so per second in a matter of a couple of minutes apiece, is a good fortune which singularly facilitates the task of a physicist."

An analytical ear of this superlative type is not possessed by many physicists in any single generation. "Thanks to M. Fouché, I have been enabled to understand how Mersenne and Chladni (to mention only a couple of names) carried out their acoustical investigations with the unaided ear."

The concluding section of this monumental work includes one volume on Astronomy, with a preface on the manner of teaching useless sciences; and one on Mathematical Geography, with a preface entitled, "Historical criticism and good sense." The latter has achieved a certain notoriety, since it involved Bouasse in a law suit, from which he emerged triumphant.

It can be only too patent that a much larger canvas would be needed to do anything like justice to a mind of such power and scope, in which so much originality of thought is allied with such virility of presentation. An endeavour has been made, by drawing where possible upon Bouasse's own writings,[1] to convey

[1] I am indebted to Professor Bouasse, and to his publishers, Messrs. Delagrave, for permission to include extracts from his works and to adapt these to my present purpose in the guise of very free translations.

a glimpse of his personality. It has not been possible even to outline what is to be found in his treatise, but there can be very little experimental work of genuine importance which does not receive due attention in one or another of his volumes. It is hardly an exaggeration to advance the claim that Professor Bouasse is the most distinguished teacher of Physics alive to-day, and in any case there is no lack of material evidence upon which to substantiate the claim. His is an unique work, for which physicists and engineers of all conditions and nationalities cannot but be grateful.

NOTES

Synthesis in Biological Problems ("Synthetic" Lignin and "Synthetic" Humus) (A. G. Norman, Ph.D., F.I.C.)

In the domain of organic chemistry, and particularly in academic pastures, synthesis is frequently worshipped as the only true god. H. E. Armstrong, in one of his periodic and characteristic diatribes, points a well-worn finger of scorn at much of the so-called research work of to-day, describing it as "Beilsteining pure and simple," deriding it as mere laboratory exercises worked out in illustration of well-known rules. It is true that there is little virtue in putting into a ring two halogen groups where one only was before, particularly if the method of accomplishing it dates back to the times of the chemical Medes and Persians, but it is no less true that all synthesis is not "Beilsteining." Synthesis as a means of confirmation of the structure and configuration of a naturally occurring product is a very different proposition. It serves then as the acid and ultimate test of the correctness of the formula as deduced from its properties and by analysis. Outstanding examples of synthesis used in this way as a constitutional tool are the work of Harrington on thyroxin or Robinson on the anthocyanins.

Recently there have been two intriguing examples of a synthetic approach to biological problems, one the source and formation of lignin, and the other the nature and properties of humus. Neither of them really involves a synthesis in the true chemical sense, and a purist may quarrel with the use of the word "synthetic" as applied to either of the products, but both comprise an inherently constructive method of attack on a problem which has hitherto been mainly considered analytically. Rigid synthesis cannot be applied either to lignin or humus since the constitution of both these bodies is unknown. However, the artificial products obtained from likely precursors in each case have apparently many points of resemblance to the naturally occurring material. Both of these papers mark a very definite advance in the problem to be solved, and are promising of important developments. They serve admirably to illustrate the possibilities of a constructive or "synthetic" line of attack in such biological problems.

Synthetic Lignin.—The chemistry of lignin and its formation

is a subject in which very little progress has been made for some considerable time. Its inertness to most reagents and the impossibility of extracting and isolating it in an unchanged condition, have meant that the starting material for researches has varied from worker to worker, there being no criteria of purity or uniformity. Its few derivatives have thrown but little light on its constitution. The evidence for a cyclic structure is still not wholly convincing, and the innumerable formulæ that have been proposed are little better than guesses ingeniously devised to explain as many of the observed reactions as possible. Since the process of lignification of the cell-wall is normally regarded as a senescent change, it might have been expected that some chemical relationship would be found between lignin and its precursor or precursors, and by examining these other cell constituents some information might be obtained as to its nature. The difficulty has been, however, that no such relationship could be found. It is true that there is some resemblance between tannins and lignin in so far as certain phenolic properties seem common to both, but not the slightest evidence exists for supposing the latter to be elaborated from the former.

Considerable interest is likely to be aroused by the recent work of L. F. Hawley,[1] of the U.S. Forest Products Laboratory, in which he demonstrates the formation of a lignin-like substance, to which he gives the name "synthetic lignin." He observed [1] that if wood were treated in a closed tube for several days at 138°, there was a large increase in apparent lignin and a diminution of carbohydrate material. In the case of white ash the increase was from 27 to 33 per cent. in eight days, and in Sitka spruce from 28 to 38 per cent. Of the carbohydrate material concerned, the pentose material not associated with cellulose seemed to have suffered the heaviest loss in the case of the ash, while in the spruce it was hexose material that had been changed.

In the most recent paper [2] he records the treatment under similar conditions, not of wood, but of the Cross and Bevan cellulose fraction prepared from wood. As is well known, this fraction contains not cellulose alone, but cellulose very intimately associated with other polysaccharide material, which in the case of hardwoods is pentose in nature, and in softwoods, a mixture of hexose and pentose, the pentose usually being quite small in amount. The Cross and Bevan cellulose fraction from both a hardwood and a softwood when treated similarly yielded a product containing considerable quantities of lignin-like material and some substance soluble in alcohol-benzene mixture. In the case of the hardwood it was the pentosans

[1] L. F. Hawley and Jan Wiertelak, *Ind. and Eng. Chem.*, 1931, **23**, 184.
[2] L. F. Hawley and E. E. Harris, *Ibid.*, 1932, **24**, 873.

which first disappeared, and in the softwood the hexosans, though in both cases the cellulose itself also suffered loss. Duplicate runs from the same material checked very closely, but with different samples of cellulose the amounts of apparent lignin produced were variable. The lignin determination, of course, is not specific for lignin—it estimates only such material as is resistant to the attack of 72 per cent. sulphuric acid in the cold, and to more dilute acid on subsequent boiling. Hawley, however, believes his " synthetic " lignin to be something which closely approaches " natural " lignin, since the ultra-violet absorption spectrum of synthetic lignin from sugar maple cellulose was typical of natural hardwood lignins. Moreover, the synthetic lignin gives the same chlorination-sulphite reactions, shows a similar resistance to hydrolysis, and has much the same reducing value as that from untreated woods. It differs in that it contains no methoxyl or acetyl groups, but can be methoxylated to a limited degree.

On the basis of these observations Hawley suggests that the observed differences between natural hardwood and softwood lignins are due to the fact that pentose units may play a large part in the formation of the first, and hexose units in the latter. He revives the theory that the transformation may possibly be due to condensation of furfuraldehyde derivatives obtained by dehydration of the sugar units. This work approaches, from an entirely new angle, the problem of the formation of lignin. If it is possible to show by similar treatment of pure polysaccharide material, pentosans, and hexosans, that a substance closely akin to natural lignin results, the theory of the carbohydrate origin of lignin will become near to being established. The treatment involved is, of course, a very violent one, and might be criticised on those grounds. It is conceivable, however, that a natural process might bring about dehydration in a similar manner. It is only necessary to cite the fixation of atmospheric nitrogen as an example of a process which *in vitro* must be violent and at a high temperature, and to compare it with the same process carried out by micro-organisms to see a possible parallel.

Synthetic Humus.—The nature of humus was for long a matter of much discussion, and its origin and formation a very controversial subject. Of recent years, however, certain views have been receiving fairly general acceptance. This has not been due to the work of any one investigator, but rather to a general accumulation of results pointing to one conclusion. Humus, of course, results in the soil from the addition of organic matter, plant materials, or plant residues, after a period of decomposition. Analyses of decomposed material and of soil in which such decompositions have taken place show that certain

plant constituents more or less completely disappear. One, however, suffers little loss, and appears to be fairly resistant to the attacks of micro-organisms. This constituent is lignin, which, together with the elaborated microbial tissue and microbial products, give rise to humus. The synthesised microbial tissue, or residues therefrom, is nitrogenous and largely protein in character. Preparations of so-called " humic acid " from soils have been shown to contain up to 5 per cent. N, present largely as amino-nitrogen, indicating a polypeptide form. Proteolytic enzymes, however, liberate little if any of this nitrogen, which is not therefore readily available to other micro-organisms. The inference from these and similar observations is that humus results from the association of lignin complexes from plant materials and protein residues from microbial sources, the manner of association being more intimate than mere mutual colloidal precipitation.

On the basis of this conclusion, two pairs of investigators have recently attempted the synthetic preparation of humus material. Hobson and Page [1] precipitated with acid a mixture of egg albumen and artificial " humic acid " from lignin. The properties of this mixture resembled that of soil humic acid in a number of respects. Waksman and Iyer,[2] in a much more detailed and extensive investigation, similarly mixed a solution in NaOH of lignin and casein, and then adjusted it to a pH of about 4·5. The precipitate obtained was washed and dried. For it they prefer the name " humus-nucleus." By introducing into the precipitating mixture various salts, and precipitating at about pH 7·0, the " humus-nucleus " complex took up the base. By this means were prepared the so-called calcium, magnesium, iron, and aluminium " ligno-proteinates." These various preparations were tested biologically, and found to be attacked only with difficulty by micro-organisms. The protein nitrogen is in some way rendered unavailable. They suggest that the linkage is a chemical one, between the amino group of the protein and a carboxyl group either of aldehydic or ketonic type from the lignin. Such a compound would be stable and possess the property of combining with bases. Since to natural humus has been ascribed a favourable influence on the growth and activities of soil organisms, the synthetic " ligno-proteinates " were tested with this in view. Cellulose decomposition in the presence of available nitrogen was assisted by the presence of these synthetic bodies. The iron ligno-proteinate had a markedly beneficial effect on the fixation of nitrogen by Azotobacter.

[1] R. P. Hobson and H. J. Page, *J. Agric. Sci.*, 1932, **22**, 497.

[2] S. A. Waksman and K. R. N. Iyer, *J. Washington Acad. Sci.*, 1932, **22**, 41; *Soil Sci.*, 1932, **34**, 43; *ibid.*, 1932, **34**, 71.

The observations of these workers provide the basis for a synthetic mode of attack on problems connected with the physico-chemical properties of soils. The high base exchange property of the artificial materials opens up the possibility of combinations with inorganic soil constituents, and developments in this field will be watched with much interest.

Use of Liquefied Gases in Industry (M. S.)

The discovery of methods of liquefying common gases has been followed by large-scale applications in industry, such as the manufacture of oxygen from air, of helium in U.S.A. by the freezing out of other constituents of natural gas, and of liquid chlorine for the treatment of municipal water supplies. In all the usual cases, however, the liquefied gas is not required as such, but is reconverted into the gaseous phase before use. Two modern instances which are exceptions have been developed, these being liquid carbon dioxide and liquid oxygen in the field of explosives.

It was Prof. Linde who first proposed in 1897 the use of liquid air or oxygen for inclusion in blasting cartridges. Some experiments were carried out at Pensburg, Bavaria, in which a mixture of charcoal plus liquid air was used. Two years later Brandt superintended the boring of the Simplon Tunnel, the blasting cartridges being of kieselguhr impregnated with paraffin and liquid air. A series of improvements followed the work of Goldschmidt, of Essen, on the combustion of powdered aluminium, for the inclusion of this metal in the blasting cartridges led to the attainment of higher explosion temperatures with higher blasting results. To-day, in numerous instances abroad, and in the iron-stone mines of North Lincolnshire, oxygen cartridges are in favour owing to the safety introduced by this novel method. The cartridges contain various carbonaceous materials and metallic powders ; in addition, in order to regulate the temperature of explosion within defined limits, cooling salts are included, these liberating their water of crystallisation. The liquid oxygen is transported from the nearest oxygen works in 50-lb. lots contained in copper vacuum vessels, which are globular in shape, and have long narrow necks to expose a minimum area of open surface. At the mines the cartridges are soaked in the liquid by placing them in small vacuum vessels, and when ready are found to sink in the liquid. Before this soaking the cartridges are harmless, and are not subjected to stringent regulations as regards storage ; the actual soaking constitutes the manufacture of an explosive, however, and yields a cartridge not uncomfortable to handle, although the inner layers are at minus 182° C. Detonation is carried out electrically ; and in case of misfire it is only necessary to

wait until the oxygen has evaporated, when the cartridge may be taken out without danger.

The Cardox cartridge, which makes use of liquid carbon dioxide, is equally efficient. A long cylindrical shell of alloyed and heat-treated steel is charged with a combustible cartridge of such materials as perchlorate plus charcoal and aluminium powder, this heating element being enclosed in a metal cage. Liquid carbon dioxide is pumped into the shell, the latter being closed by a mild-steel disc which is renewable and ruptures at some predetermined pressure of from 10,000 to 30,000 lb. according to requirements and size of shell used. In one-eighty-fifth of a second the heat generated by the heating cartridge gasifies the charge of liquid carbon dioxide, thus liberating a large volume of gas at the back of the mineral face. This slow, pushing effect is no detonation, and yields no flame; indeed, the converse is obtained, for not only is carbon dioxide a non-supporter of combustion, but it is liberated as a cold gas from the rapid evaporation of a liquid. A compressing unit is required at the head of the mine for effecting the transference of the liquid carbon dioxide from the gas cylinders to the steel cartridges.

Masurium (Eka-manganese), the Element of Atomic Number 43 (J. G. F. Druce, M.Sc. (Lond.), R.Nat.Dr. (Prague), F.I.C.).

In 1925 the discovery of two new elements was announced [1]. They were the missing congeners of manganese whose existence had been predicted by Mendělějev, and to which he gave the provisional names eka- and dvi-manganese. The main chemical and physical characteristics of dvi-manganese (rhenium), the element of atomic number 75, have been established, and accounts of its properties and compounds have already appeared in SCIENCE PROGRESS [2], but no great advance has yet been made in connection with the isolation of eka-manganese, the element of atomic number 43, to which the name masurium was assigned by Noddack, Tacke, and Berg [1].

These investigators estimated that the lithosphere contained 10^{-12} of eka-manganese and 10^{-11} of dvi-manganese compared with 7×10^{-4} of manganese and 10^{-2} of iron. Later, they revised this estimate, and suggested [3] that the two new elements were present in equal amounts, namely, 10^{-9}. On this assumption it seems remarkable that so little progress has been made in the study of masurium whilst so much is now known regarding rhenium.

The German investigators, who have examined 1,800 minerals and 21 meteorites for the new elements, claim to have detected masurium, by X-ray spectroscopic analysis, in platinum ores, columbite, sperrylith, gadolinite, and fergusonite [1], and

(later) in tantalite and possibly chrome iron ore, olivine, and pitchblende [3]. The evidence upon which the detection of the new element depends is the appearance of its characteristic lines in the X-ray spectra. The K_{α_1}, K_{α_2}, and K_{β_1} lines have been identified as follows:

WAVELENGTHS IN ÅNGSTRÖM UNITS

	K_{α_1}	K_{α_2}	K_{β_1}
Found	0·672	0·675	0·601
Calculated . . .	0·6734	0·6779	0·6000

The nearest approach to the isolation of masurium is that described by W. and I. Noddack [4], who worked up the mineral columbite to yield a final sulphide product containing from 0·2 to 1 per cent. of masurium, and which it was said could be further enriched. The amount of the new element present was enough to enable its optical arc and spark spectral lines to be identified, but not enough to serve for an examination of its chemical properties. The Noddacks, however, predicted that the lower oxides, to which they assigned the formulæ, MaO, Ma_2O_3, and MaO_2, would be dark coloured and probably insoluble in acids. The two higher oxides, MaO_3 and Ma_2O_7, should be light, and combine with water to form acids analogous to manganic and permanganic acids. The highest oxide was predicted to have a melting-point of about 350–400° C. They also ventured a forecast concerning the nature of the halides and sulphides of the new element.

With reference to the physical properties, Noddack and Tacke anticipated that the molecular weight of masurium will be between 98 and 99 [1] or 99·5 [3]. Its density was given as about 11·5 and its melting-point as about 2,300° Absolute.

From theoretical reasoning, E. W. Washburn [5] came to the conclusion that the atomic weight of masurium would be 97·5 or 98·8, whilst F. H. Loring has deduced [6] that the element should consist of two isotopes, 99 and 101. Reference to the Periodic Table shows that the atomic weight should be between molybdenum 96 and ruthenium 102. The same three authorities gave estimates of the atomic weight of rhenium (dvi-manganese), and the closest approximation to the result obtained practically by Hönigschmid and Sachtleben (186·31) was that of Loring (187) [7].

In the course of investigations upon rhenium other observers have had indications of the presence of masurium in the rhenium concentrates. Thus, Heyrovský and Dolejšek [8] state that in their polarographic studies of manganese salt solutions with the dropping mercury cathode they noticed a wave at − 1·15 volt in the deposition potential curves. This wave they attribute

to masurium, having obtained X-ray spectrographic evidence in support of this view.

It is nevertheless apparent that little is yet known concerning the properties and nature of masurium. Researches on the congeners of manganese have hitherto been directed towards a study of rhenium, and perhaps it may be due to rhenium preparations being contaminated with masurium that has given rise to some of the discrepancies in the observations and deductions of different investigators. Within the last two years three monographs on rhenium have appeared, namely, *Rhenium (and Masurium)*, by P. M. Tyler, U.S. Bureau of Mines, 1931; *Das Rhenium*, by Dr. W. Schröter, Stuttgart, 1932; and *Renij*, by Dr. E. S. Kronman, Moscow, 1932. All three make only a passing reference to masurium.

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A Photo-electric Organ (S. K. L.).

In recent years there has been a steady growth of the interest in musical instruments in which the acoustic frequencies are generated in electrical circuits, the transformation into sound usually being accomplished by means of a loud-speaker. These devices are at present more popular on the Continent, where this "electronic music" is finding its way into public performances of bands and orchestras.

An exceptionally attractive instrument of this class was demonstrated by G. T. Winch, of the G.E.C. Research Laboratories, at the Physical Society's Exhibition at South Kensington on January 3, 4, and 5. This instrument, which was described as a photo-electric organ, was exhibited only, as an experimental arrangement, and was restricted, for the sake of simplicity, to a short range of musical frequencies. The principle upon which it operates is very neat, particularly with regard to the manner in which the characteristic tones of various musical instruments are obtained.

A photo-electric cell is the origin of the electric oscillations. The light which falls on this cell originates in a number of very

small lamps. Each lamp is associated with a lens, and the beam of light passes through narrow radial slits cut in a disc of metal, or blackened glass, which rotates at constant speed. The light is then reflected from a large concave mirror, co-axial with the rotating slotted disc, into the photo-electric cell located at the focus. The radial slits are spaced uniformly around the disc, so that when the latter is rotated at a constant speed, the light from any one lamp generates a succession of electric impulses in the photo-electric cell, which gives acoustic frequency after being amplified and fed to a loud-speaker. Sets of radial slits on circles of various diameters are made to give various frequencies, according to the frequency at which the slits transmit light from the corresponding lamps. An ordinary keyboard has contacts fitted to the keys which are connected to the lamps so that each lamp lights up when the corresponding key is depressed.

The tone, or colour, of each note is determined by a simple yet ingenious device. Between each lamp-lens system and the reflecting mirror, and behind the slotted disc, is placed an actual picture on glass of the wave-form of the sound which it is desired to produce. The length of the picture coincides exactly with the circumferential distance between successive slits in the disc. As the slit traverses the picture, the amount of light which passes from the lamp to the mirror and photo-electric cell is modulated according to the wave-form in the picture. The electric impulses from the photo-electric cell vary in a corresponding manner and the loud-speaker thereby produces the desired tone. These wave-form pictures can be produced in large numbers photographically, so that the whole compass of the organ could be readily equipped with many sets of various tones, or stops. Not only can the tones of known instruments be rendered, but entirely new wave-forms can be introduced. The whole system is capable of considerable flexibility in various respects such as amplitude, "attack," tremolo, and location of controls and loud-speaker. Unfortunately, transient effects cannot be produced in the present design.

A complete organ built upon these lines would, of course, be rather larger and more intricate than the experimental apparatus exhibited, but considering the admirable performance obtainable from it, the system is very simple and effective.

Infra-red Photography (S. K. L.).

A lecture on recent developments in Infra-red Photography at the Royal Society of Arts on January 18, by Olaf F. Block, President of the Royal Photographic Society, attracted a very large audience. After discussing the theoretical aspect of the subject, the lecturer dealt at some length with the practical

applications. The theory of the treatment of photographic plates by dyes in order to render them sensitive to infra-red radiation is not yet fully understood, although several suggestions have been put forward. The sensitivity is not due merely to absorption, and the amount of dye required is extremely minute. In the developing process for these sensitised plates, it is permissible to use a green safe light. Ordinary cameras may be used, excepting certain types having wooden frames transparent to infra-red. A small adjustment for the longer focus is necessary. The sensitivity to low-temperature radiation was clearly demonstrated by lantern slides showing ordinary flat-irons at 400° Centigrade.

One of the most important and useful applications is in long-distance and aerial photography. This is rendered possible by the low absorption of infra-red radiation by mist and clouds. As long ago as 1924 photographs of mountains 150 miles distant were obtained. More recently the distance has been increased to 330 miles, and a photograph of a long range of the Andes has been secured which shows the curvature of the earth. An excellent slide of the Dover cliffs taken in France was shown. Infra-red photography is of considerable service to newspapers. Photographs of the crowds at the Cenotaph on Armistice Day taken by infra-red plates, and by ordinary plates, showed very clearly the advantage gained by the infra-red process in outdoor photography in a misty atmosphere. The fact that the infra-red component in daylight does not necessarily follow the variation in light intensity constitutes a difficulty in estimating the requisite exposure. An actinometer for infra-red is at present being developed. A characteristic of infra-red landscape photography is the white appearance of foliage. This arises from the excellent infra-red transmission—and reflection—property of chlorophyll.

In the case of clothing materials, there is no uniform relation between infra-red and visible light. A selection of black cloths might include all shades in an infra-red photograph. Woods also differ very greatly, but all metals are opaque : hence the superiority of metals for infra-red camera construction. The usual photographic black paper is opaque even though it be thin. A most interesting case is the examination of documents suspected of forgery or other alteration. A slide was shown of an ancient document censored by the Inquisition, in which the censor's ink was transparent when photographed by infra-red. Some amusing slides of the results obtained in portraiture were shown. For instance, a negro gentleman appeared in the infra-red photograph to have marked Mongolian characteristics. In microscopy, the new photography promises to be of considerable utility, particularly in the examination of the interior

structure of small insects. The advantages gained in this field were clearly shown by comparative slides. There are possibilities also in the application of infra-red photography to psychical research. Improvements in planet photography have been effected: for instance, in the case of the Nebula in Orion, the ordinary photographs are confused by scattered light, but by infra-red they are perfectly clear.

The lecturer demonstrated a number of effects of infra-red radiation, making use of two photo-electric cells, one sensitive only to visible light, the other sensitive only to infra-red. The electric responses were amplified and fed to a loud-speaker. By this means the absorption and transmission of various materials, including two different black cloths and a green leaf, were shown. In conclusion, the lecturer showed a slide of an infra-red photograph of the audience taken at the commencement of the lecture. The exposure for this lasted only a few seconds in almost complete darkness.

Luminous Discharge Lamps (S. K. L.).

Recent developments in luminous discharge lamps suggest that a new era in electric lighting is approaching. The present situation was admirably presented in an address by Mr. C. C. Paterson to the Illuminating Engineering Society on November 8, 1932. Great confidence was expressed in the new lamps. The discharge tube has far wider limits to progress than the incandescent filament lamp, particularly with regard to efficiency. In colour the discharge lamp has a wide flexibility, but it is not always possible to obtain what is desired. While, however, there appears to be a definite future for the new lamps, the filament lamp is too simple and effective to be readily displaced.

The usual form of cold cathode discharge tube has two electrodes with no visible connection between them, and is filled with gas of the correct quantity and purity. Under the action of the applied electric field, the comparatively few natural ions which are always present are accelerated and produce vast numbers of ions by collision. The conductivity of the ionised gas is then very high, and in fact the tube may have a negative resistance characteristic, which calls for certain auxiliary equipment in practical application. The pressure of the gas is an important question. At high pressures a very high voltage is required to pass a current, and the discharge would take the form of a spark. At very low pressures also a high voltage is required because the gas atoms are farther apart, so that the chance of ionisation is smaller. Between these extremes, at the correct low pressure, the discharge takes the form of a glow. As a result of collisions between the accelerated ions and the gas atoms, the latter become energised in

having their electrons transferred to orbits of higher potential energy, or even removed from the boundaries of the atoms. Light is produced when the electrons return to their normal orbits. The colour of the light emitted is fundamentally related to the energy change. The frequency of the light is proportional to the energy emitted by the atom during the process of radiation. This implies that each kind of atom has its own characteristic set of frequencies. All frequencies do not have the same intensity. In consequence, the spectrum of a discharge of this nature consists of a number of lines as distinct from the continuous spectrum of an incandescent lamp.

The discharge in the cold cathode tube consists essentially of two parts—that immediately surrounding the electrodes, and that which constitutes the main column. The latter gives most of the light, while the former is an unavoidable difficulty, and is associated with a high voltage drop, known as the cathode fall, and with cathodic sputtering which governs as a rule the life of the tube. In the sputtering process, the gas atoms are entrapped on the surface of the glass tube and the pressure falls eventually to an unsatisfactorily low value.

In the recently developed hot cathode tubes, heavy currents may be passed without an increase in the size of the electrodes. The hot cathode is an electrically heated alkaline earth oxide electrode. By the use of these electrodes, the cathode fall is greatly reduced, and the voltage drop per foot of the tube is much less than in the cold cathode tubes. The current is now limited only by the heat dissipation of the tube. The running voltage is conveniently low, and no step-up transformer is required. A choke to limit the current and a small transformer to heat the filaments are required. The starting voltage is rather high, and is usually provided by a small high-frequency Tesla coil.

The choice of gas used in the tube is determined by several important requirements. Colour mixing by gas mixing is not a simple matter, as the gas with the lowest stimulating voltage will give the dominant hue. Neon and mercury can be made to give white light, but the practical difficulty is to maintain the temperature sufficiently constant to ensure correct vapour pressure.

Since the gas discharge does not obey Ohm's law, the power factor is not unity. However, by adding a suitable capacity to the circuit and by running the tubes on leakage transformers, a power factor of about 0·95 can be achieved. It should be noted that on account of the rapid fluctuation of light intensity according to the alternations of the supply voltage, the "flicker" effect on the visibility of moving objects is rather more apparent than in the case of the incandescent lamp.

In photometry, some very broad issues arise. Serious complications are encountered when an attempt is made to measure the output of coloured discharge tubes. A reasonable approximation, however, is obtained by comparing the coloured discharge with the light from a tungsten lamp passed through a filter designed to match the colour. Several factors affect the efficiency of the hot cathode lamp. Some gases and vapours are intrinsically more efficient as light sources than others. A loss of energy arises from various wasteful processes in the tube, including elastic collisions of the gas atoms, and appear as a rise in the temperature of the tube. There are losses also in the reactors used to counteract the negative resistance, and very small losses in the condensers for correcting the power factor.

The development of hot cathode tubes has been very rapid in the last year or two, and they have already found important practical applications. Neon or mercury tubes (the latter in either clear or green glass) in parabolic reflectors are very effective in colour floodlighting, etc. For this purpose the efficiency is greatly in excess of that of ordinary incandescent lamps and colour filters. The combination of neon and mercury tubes behind opal glass may be used to give good colour rendering. A new type of lamp which has recently been developed by the G.E.C. Research Laboratories gives an efficiency of 40 lumens per watt for a 400-watt lamp, compared with 15 lumens per watt for the corresponding tungsten filament lamp. Still higher efficiencies have been obtained in experimental tubes. This type is particularly suitable for street lighting. At present it gives a whitish-blue light, and is deficient in red, but this will be corrected later. A street in Wembley has been illuminated by these lamps since July 1932, and further work in this direction is in hand. A similar type of lamp, which utilises sodium vapour, has been developed in Germany and Holland. The light from this lamp is practically pure yellow and is not very suitable for general or street lighting. Road sections have been lighted by these lamps in Holland—in Zurich—and recently in this country. The yellow lamps may be suitable in special cases, such as arterial road lighting, where good colour rendering is not required. The next developments in hot cathode lamps will have to be directed towards improving first the colour and then, still further, the efficiency.

Notes and News

Professor Karl Pearson, who is retiring from the Galton chair of Eugenics in the University of London at the end of the present session, has been awarded the Rudolf Virchow medal by the Berlin Gesellschaft für Anthropologie, Ethnologie und Urgeschichte.

Sir Frank Dyson, the Astronomer Royal who retired on February 28, has been succeeded by Dr. H. Spencer-Jones, H.M. Astronomer at the Cape Observatory. Dr. Spencer-Jones was educated at the Latymer Upper School, and at Jesus College, Cambridge. He served as chief assistant at Greenwich from 1913 to 1923, when he received his appointment at the Cape. He contributed the notes on Recent Advances in Astronomy to SCIENCE PROGRESS from their first appearance in 1917 until his departure from England rendered further contributions impracticable. Dr. Spencer-Jones is succeeded at the Cape Observatory by Dr. J. Jackson, chief assistant at Greenwich.

Prof. L. N. G. Filon, C.B.E., F.R.S., has been elected Vice-Chancellor of the University of London for the remainder of the session 1932–33 in succession to the late Mr. J. L. S. Hatton.

Mr. H. T. Tizard, Rector of the Imperial College of Science and Technology, has been appointed to succeed Sir Richard Glazebrook as chairman of the Aeronautical Research Committee.

Mr. T. Franklin Sibly, Vice-Chancellor of the University of Reading, has been appointed to be a member of the Advisory Council of the Privy Council for Scientific and Industrial Research.

The Gold Medal of the Royal Astronomical Society for 1933 has been awarded to Dr. V. M. Slipher, director of the Lowell Observatory, for his spectroscopic work on the planets, stars, and nebulæ.

The Council of the Geological Society has awarded the Wollaston medal to Prof. M. Boule of Paris, for his work on the geology and palæontology of the Tertiary period; the Murchison medal to Dr. A. L. Dutoit of Johannesburg, for his work on the geology of South Africa, and the Lyell medal to Mr. J. E. Richey of the Geological Survey of Great Britain, for his researches on the Tertiary volcanic geology of the British Isles.

Prof. E. J. Salisbury will preside at the annual congress of the South Eastern Union of Scientific Societies to be held at Norwich from June 7 to 10.

Prof. C. B. Fawcett has been chosen to be first president of the newly formed Institute of British Geographers. Membership of the Institute is, at present, limited to members of the staffs of university departments of geography in Britain.

The meeting of the British Association this year will be held at Leicester during the period September 6–13 under the presidency of Sir F. Gowland Hopkins. The presidents of the various sections will be: Section A (Mathematics and Physics), Sir Gilbert Walker; B (Chemistry), Prof. R. Robinson; C (Geology), Prof. W. G. Fearnsides; D (Zoology),

Dr. J. Gray; E (Geography), the Right Hon. Lord Meston; F (Economics and Statistics), Prof. J. H. Jones; G (Engineering), Mr. R. W. Allen; H (Anthropology), the Right Hon. Lord Raglan; I (Physiology), Prof. E. D. Adrian; J (Psychology), Prof. F. Aveling; K (Botany), Prof. F. E. Lloyd; L (Education), Mr. J. L. Holland; M (Agriculture), Dr. A. Lauder.

The sixteenth International Geological Congress will be held in Washington during the week July 22–29. Information concerning the arrangements for the meeting may be obtained from the Geological Survey, Washington, D.C.

An international congress on Physical Chemistry will be held in Paris at the end of October. It has been arranged to celebrate the twenty-fifth anniversary of the formation of the French Society of Physical Chemistry. All necessary particulars may be obtained from Dr. Ch. Marie, 9, rue de Bagneux, Paris, 9e.

Prof. Einstein has accepted a life appointment as head of the school of mathematics in the new Institute of Advanced Study at present located in Princeton University. Dr. Abraham Flexner is director of the Institute, which was formed as a result of a grant of 5 million dollars from Louis Bamberger and Mrs. Felix Field.

Prof. A. C. Dixon has been elected president of the London Mathematical Society for the current session, Mr. Conrad Beck president of the Royal Microscopical Society, and Dr. W. A. Rogers president of the Royal Society of South Africa.

We regret to have to record the announcements of the death of the following men, well known in scientific circles, during the past quarter: Mr. C. F. Beadles, curator of the pathological collection at the Hunterian Museum; Dr. J. J. Carty, until 1930 chief engineer to the American Telephone and Telegraph Co.; Mr. T. H. Coward, naturalist; Prof. R. Donaldson, pathologist of St. George's Hospital; Prof. Paolo Enriques, president of the last International Congress of Zoology; Mr. F. Finn, naturalist; Mr. J. L. S. Hatton, Vice-Chancellor of the University of London and principal of East London College; Prof. A. B. Hill, lately professor of hygiene in the University of Birmingham; Prof. James Johnstone, professor of oceanography in the University of Liverpool; Dr. M. E. MacGregor, entomologist; Mr. H. A. Roberts, until recently secretary to the Appointments Board of the University of Cambridge; the Rev. J. Roscoe, honorary Canon of Norwich, anthropologist; Prof. C. M. Thompson, Emeritus professor of chemistry at University College, Cardiff; Sir J. Arthur Thomson, zoologist.

The Royal Society Mond Laboratory at Cambridge was opened by the Right Hon. Stanley Baldwin on Friday, February 3. The erection of the laboratory is the outcome of the

work of its Director, Dr. P. Kapitza, and was rendered possible by a grant of £15,000 from the Royal Society. The equipment comprises the apparatus required for the production of intense magnetic fields and plant for the liquefaction of nitrogen, hydrogen, and helium so that the behaviour of matter at very low temperatures and in strong magnetic fields can be investigated. The architectural work has been carried out according to the designs of Mr. H. C. Hughes, and the brickwork near the main entrance is adorned by a carving by Eric Gill which appears to represent a crocodile. The suitability of this ornamentation is not immediately obvious.

At a Friday evening lecture at the Royal Institution on June 3 last year Prof. McLennan showed, for the first time in this country, a lead ring immersed in liquid helium and carrying a current which was induced in it by Prof. Keesom at Leiden on the morning of the lecture. This experiment Prof. McLennan repeated at another lecture at the Royal Institution on January 31. To produce the current the ring is placed in a vacuum flask and a magnet is held near it. Liquid helium is then poured into the flask and, when the ring has cooled below the transition temperature, the magnet is removed, thereby producing a current giving a magnetic flux equal to that originally given by the magnet. Those fortunate enough to be present at the lecture were able to inspect the liquid helium through an unsilvered strip down the side of the flask. It is a clear colourless liquid, indistinguishable, in its appearance in the flask, from water.

The Cambridge University Press announces two new books of outstanding interest. Sir Arthur Eddington has written on *The Expanding Universe*, introducing the cosmical constant, and Sir James Jeans has in preparation a book to be titled *The New Background of Science*, and designed to appeal both to the physicist and to the general reader. In addition, Prof. Whitehead has written a volume to round off the ideas expounded in his earlier books, *Science and the Modern World* and *Process and Reality*. He calls it *Adventures of Ideas*.

Among the papers printed in the *Journal of Research* published by the Bureau of Standards (Washington, D.C.) during the last quarter were (*a*) a paper by Hidnert and Sweeney on the thermal expansion of lead, which contains a list of all the values of its coefficient of linear expansion obtained by various observers from Musschenbroek (1740) to the present day. The value of the coefficient increases from 0·0000251 (− 250° C. to 20° C.) to 0·0000313 (20° C. to 300° C.), and for the range 20° C. to 100° C. is 0·0000291 per degree C. (Nov. 1932). (*b*) A description of the construction and performance of a platinum resistance thermometer with a coiled wire wound on

a mica frame. A double helical winding is employed, and as a result a 25-ohm coil can be contained in a space 2 cm. × 0·5 cm., which is little larger than the bulb of an ordinary mercury-in-glass thermometer. The thermometers constructed at the Bureau were hermetically sealed and filled with helium to reduce thermometric lag. (*c*) An account of a convenient arrangement for measuring thermal expansion by Fizeau's interference method (G. E. Merritt, January 1933).

The *Annual Report* of the Director of the Bureau of Standards of the United States contains a number of statements of general scientific interest. The refractive index of water has been determined for 5° C. intervals between 0° C. and 60° C. for several wavelengths in the visible spectrum correct to within 3 units in the sixth decimal place. The concentration of the hydrogen isotope of mass 2 in water has been raised from 1 part in 30,000 to 1 in 1,000 by fractional electrolysis. In the process the density of the water increases by 16 parts in 100,000. An attempt was made to discover why some samples of soda-lime glasses are able to transmit as much as 85 per cent. of the ultra-violet rays reaching us from the sun, and it appeared that the presence of iron in the glass has a very important effect on this transmission. The freezing-point of iridium has been found to be 2,450° C., and a copper-lead mixture has been found suitable for use as a bearing metal. A substitute material for boot soles has been made of heavy cotton duck and synthetic resin, and another synthetic resin has been found to replace shellac as a stiffener for felt hats.

The Bell System *Technical Journal* for October 1932 contains the paper presented by Dr. C. J. Davisson to the International Electrical Congress held in Paris last July, descriptive of the growth of our ideas concerning the electron from the time of Faraday up to the present day. Rupp's experiments on the effects of magnetic fields on electron beams indicate that regarded as particles they possess spin, while regarded as waves they have a wavelength given by the ratio of Planck's constant h to their linear momentum—a duality of character which makes it impossible for us to form any kind of picture of their nature, if, indeed, "they" have any. The same issue of the *Journal* contains the first part of an article by Karl Darrow on high-frequency phenomena in gases. It includes an excellent account of the results obtained by Appleton and his students during the last three or four years.

The Imperial Institute has issued a second edition of its monograph on *Borates* in their series on the Mineral Resources of the British Empire and Foreign Countries (H.M. Stationery Office, price 9*d.*, or, by post, 10*d.*). The fall in the price of borax in recent years has led to its wider use in industry.

It is employed in the manufacture of glass, pottery, adhesives, and paper; in leather dressing, dyeing, enamelling, and metallurgy. Its many domestic uses include that of a water softener and cleanser, and its derivative, perborate of soda, is an important bleaching agent. Manganese borate is used in the manufacture of paint, printing inks, and linoleum. The mild antiseptic and detergent properties of boric acid and borax render them of value in pharmacy. So far, the demand for metallic boron has been small; some borides have possibilities as abrasives and in the steel industry. The sources of the raw material include the Californian deposits of kernite (borate of soda), which now furnish a very large proportion of the world's requirements of crude borates, deposits of pandermite (calcium borate) in Turkey, and volcanic emanations which in Italy constitute an important source of boric acid.

The January number of the *Transactions of the Norfolk and Norwich Naturalists Society* contains the Presidential Address by Prof. E. J. Salisbury on "The East Anglian Flora." This is a study of comparative plant geography occupying 75 pages of text and illustrated by no less than 107 distribution maps and 8 half-tone plates from photographs of some of the rarer species. These maps not only show the distribution in the British Isles, including the latest records up to the time of publication, but in many instances the relative frequency in the comital and vice-comital areas is indicated by means of differential shading. From the data here presented a number of important conclusions are deduced which, having regard to the rich and representative character of the East Anglian Flora, apply to the British Flora as a whole and not merely to the area from which the author has taken his subject-matter. The author divides the constituent species into various "components" and these again into "elements," a grouping based upon the areas where they characteristically occur upon the Continent of Europe. These areas have, however, been utilised as indicators of the climatic preferences of the species concerned, so that designations such as "oceanic," "Continental," are employed in place of regional appellations.

The predominance of the climatic factor is clearly demonstrated and the rôle of edaphic and biotic factors in accentuating or diminishing the effect of climate is considered in its various aspects. The time factor and the various types of dispersal are shown to have little, if any, effect upon the type of distribution, and the presence of species in Ireland or their absence from that country is shown to correspond to the climatic preferences of the species concerned. Separate copies can be obtained from the Hon. Secretary, Dr. S. H. Long, 31 Surrey Street, Norwich, at 5s. post free.

CORRESPONDENCE

To the Editor of SCIENCE PROGRESS

I. *From* J. T. CUNNINGHAM, M.A.

DR. FISHER ON BATESON AND DE VRIES

SIR,—In the October number of SCIENCE PROGRESS is an article on the "Bearing of Genetics on Theories of Evolution," by Dr. Fisher, in which he states that Bateson and de Vries "seized upon the discontinuous hereditary factors demonstrated by Mendel's work as though these had been specific differences, instead of differences between close varieties: whereas we now know that forms which are ranked as specifically distinct differ as a rule not in one but in a large assemblage of Mendelian factors." With regard to de Vries, Bateson (Mendel's *Principles of Heredity*, 1909, p. 225) states that he has incautiously defined with some strictness the differences between varietal and specific distinctions, declaring that it is the property of varietal characters alone to exhibit Mendelian heredity. I have no doubt that Bateson's description of de Vries's views is correct, and it is evident that they were the direct opposite of those which Dr. Fisher attributes to him. Bateson declares himself unable to accept so vast a generalisation, but I find nowhere in Mendel's *Principles*, nor in the *Problems of Genetics*, 1913, anything to justify Dr. Fisher's assertion that Bateson regarded Mendelian factors in general as specific differences. Considering the great amount of Mendelian research carried out by Bateson on varieties and variations of cultivated and wild animals and plants, the statement that he mistook differences of varieties for specific differences is not only erroneous but absurd. The problem that most perplexed Bateson was the evolution of species, convinced as he was that the great majority of their characters and their variations were not adaptive and therefore not due to any process of Natural Selection, to which Dr. Fisher and other modern geneticists attribute so much influence, using the term with a meaning that has little or nothing to do with what Darwin meant by it.

Bateson states that plenty of the characters now known to segregate would be sufficient to constitute specific differences

in the eyes of most systematists, but the question is whether certain kinds of differences segregate and certain others do not, and whether the conception of species attaches with greater propriety to the non-segregating. In his *Problems of Genetics*, chap. V, he writes that the distinctions between species are usually such as might be caused by the presence, absence, or inter-combination of groups of Mendelian factors, but that they are so caused the evidence is not yet sufficient to prove in more than a very few instances.

It is evident that Dr. Fisher is only imperfectly acquainted with Bateson's work or his conclusions, and also that he fails to appreciate the great value of his work and the position he held as pioneer and leader of Mendelian research for so many years.

Yours faithfully,
J. T. CUNNINGHAM.

35, WAVENDON AVENUE,
LONDON, W.4.
December 3, 1932.

II. *From* R. A. FISHER, Sc.D., F.R.S.

I suppose the futility of controversy, especially when carried out with vehemence, is chiefly due to a careless reading of other people's words. Dr. Cunningham begins by quoting my words correctly, but continues by reproving me severely for two very distorted versions of them :

(i) " Fisher's *assertion* that Bateson regarded Mendelian factors in general as specific differences " ; and

(ii) " The *statement* that he mistook differences of variety for specific differences."

Obviously neither the assertion nor the statement is mine. What I do assert, and what I had thought was familiar to every student of the subject, was that De Vries and Bateson supported their pre-Mendelian belief in the discontinuous origin of specific forms on the more recently demonstrated fact of the discontinuity of Mendelian factors. This argument would have been a strong one had the Mendelian discovery been made in inter-specific crosses. It was a very weak one in view of the actual facts, because the existence of numerous factors segregating within each species had already made it extremely improbable that the specific differences recognised by systematists were ever based on only a single factor.

Even in 1909, the year for which Dr. Cunningham quotes Bateson's opinion, it is evident that Bateson still held to the belief that many of the taxonomists' species would be shown experimentally to be simple segregates, and therefore, inferenti-

ally, not distinguished by adaptive characters. In the paragraph immediately preceding that mentioned by Dr. Cunningham, he states in round terms :

" We may even be certain that numbers of excellent species universally recognised by ornithologists or entomologists, for example, would, if subjected to breeding tests, be immediately proved to be analytical varieties differing from each merely in the presence or absence of definite factors."

I think I am right in saying that in the intervening period of intense genetical research throughout the world, in no single case have the heritable differences between two " excellent species universally recognised " by systematists been analysed genetically ; in spite of the wide interest which such an analysis would arouse, and of the almost universal belief, which I share, that such an analysis is theoretically possible. It is not a remote inference that such forms differ, as a rule, not in one but in a large assemblage of Mendelian factors.

As to whether to disagree with the early, and, as I think, hasty opinions of a pioneer, is to give evidence of imperfect acquaintance with his conclusions, and a failure to appreciate other aspects of his work, this point must, I suppose, remain a matter of opinion, as between the different kinds of minds which interest themselves in Science.

R. A. F.

ESSAY-REVIEWS

THE THEORY OF LINEAR OPERATORS. By Prof. G. Temple, Ph.D., D.Sc. Being a review of **Linear Transformations in Hilbert Space and their Applications to Analysis**, by M. H. Stone. [Pp. viii + 622.] (American Mathematical Society Colloquium Publications, vol. xv, 1932. Price $6.50.)

During the years 1929–30, Prof. Stone, of Yale University, contributed to the Proceedings of the National Academy of Sciences a series of three papers on "Linear Transformations in Hilbert Space," which brilliantly summarised the leading results obtained by the author on the geometrical, analytical, and operational aspects of the theory. Similar results had previously been obtained by J. v. Neumann, and the present volume gives a formal exposition of the discoveries made independently and conjointly by these two authorities.

The theory developed in this volume is urgently required for the adequate mathematical expression of quantum mechanics, and every reader will regret that lack of space has led the author to omit a chapter which had been planned to discuss the applications of the theory to modern atomic physics. But this branch of mathematical physics is far from being the only field of application found for the abstract theory discussed in Stone's monumental treatise. The general theory throws a flood of light on numerous problems of pure and applied mathematics and gives a unified treatment of many diverse questions, as, for example, the theory of Jacobi matrices, differential equations, integral equations, Fourier transforms, Parseval and Riesz-Fischer theorems.

A rather elaborate mathematical technique is required for the rigorous discussion of the geometry of Hilbert space. The theory of measure and of Lebesgue integration are fundamental, the integrals of Stieltjes, of Radon-Stieltjes, and of Hellinger are indispensable, and in the treatment of limiting processes the concept of convergence in the mean (or "strong" convergence) dominates the theory. Nor is the analysis restricted to functions of a real variable. The theory of self-adjoint transformations centres around the integral

$$I(l\,;\rho) = \int_{-\infty}^{+\infty} \frac{d\rho(\lambda)}{\lambda - l},$$

where $\rho(\lambda)$ is a complex function of bounded variation and l a complex parameter. The fundamental theorem required here is that $\rho(\lambda)$ is uniquely expressible by means of a contour integral of $I(l\,;\rho)$.

The most important types of operators discussed by Stone are self-adjoint operators T, such that $T = T^{\dagger}$ (the adjoint of T), unitary operators U, such that $U^{\dagger}U = I$ (the identical operation), and systems of projective operators $\{E_\lambda\}$, such that

$$\begin{aligned}&E_\lambda E_\mu = E_\mu E_\lambda = E_\mu \text{ if } \mu \leqslant \lambda,\\ &E_\lambda \to O \text{ or } I, \text{ as } \lambda \to -\infty \text{ or } +\infty,\\ &E_{\lambda+0} = E_\lambda,\ E_\lambda^{\dagger} = E_\lambda.\end{aligned}$$

Among the wealth of results obtained, it is difficult to single out any particular theorems for special mention, but probably the most important are those which give the canonical form for self-adjoint and unitary operators. A brief sketch of these will serve to illustrate the methods employed in the study of linear transformations.

If T is a self-adjoint operator, then for all non-real values of l, and possibly for some real values, $T_l = T - lI$ has a unique inverse $T_l^{-1} = R_l$. In the theorem alluded to in the last paragraph we replace $I(l\,;\rho)$ by $(R_l f, g)$, the scalar product of $R_l f$ and g, where f and g are any two elements of the Hilbert space. It then follows that there exists a unique function $\rho(l\,; f, g)$ such that

$$(R_l f, g) = \int_{-\infty}^{+\infty} \frac{1}{\lambda - l}\, d\rho\,(\lambda\,; f, g).$$

It can then be shown that there exists a system of projective operators, $\{E_\lambda\}$, such that

$$\rho(\lambda\,; f, g) = (E_\lambda f, g),$$

whence

$$R_l = \int_{-\infty}^{+\infty} \frac{1}{\lambda - l}\, dE_\lambda.$$

We now define a projective operator E^* and an element f^* by the equations

$$E^* = E_\beta - E_\alpha \qquad (\alpha < \beta)$$

$$(f^*, g) = \int_\alpha^\beta \lambda d(E_\lambda f, g), \text{ (all } g).$$

Then

$$(R_l (f^* - lE^* f), g) = (E^* f, g),$$

i.e.

$$R_l (f^* - lE^* f) = E^* f,$$

and

$$(T - lI)\, E^* f = f^* - lE^* f.$$

Hence

$$TE^* f = f^*,$$

and
$$(\mathrm{TE}^* f, g) = \int_a^\beta \lambda d(\mathrm{E}_\lambda f, g).$$

Since this is true for all a and β, if $a \to -\infty$ and $\beta \to +\infty$
$$(\mathrm{T}f, g) = \int_{-\infty}^{+\infty} \lambda d(\mathrm{E}_\lambda f, g),$$
and
$$\mathrm{T} = \int_{-\infty}^{+\infty} \lambda d\mathrm{E}_\lambda.$$

This is the canonical form of a self-adjoint operator T.

If U is a unitary operator, its spectrum, *i.e.* the set of its "proper values," lies on the unit circle $|l| = 1$, and its discrete spectrum, *i.e.* the set of values of l for which $\mathrm{U} - l\mathrm{I}$ has no inverse, is at most enumerably infinite. Hence there exist points on the unit circle which are not proper values of U. If ξ is such a point, there exists a unique self-adjoint operator H such that
$$\mathrm{U} = \xi \frac{\mathrm{H} - \iota\mathrm{I}}{\mathrm{H} + \iota\mathrm{I}}. \quad \text{(Cayley's transformation.)}$$

Hence for any pair of elements f and g,
$$(\mathrm{U}f, g) = \xi \int_{-\infty}^{+\infty} \frac{\lambda - \iota}{\lambda + \iota} d(\mathrm{E}_\lambda f, g).$$

If we introduce a new variable μ and a new set of projective operators $\{\mathrm{F}_\mu\}$ such that
$$\lambda = -\cot \pi\mu \text{ and } \mathrm{F}_\mu = \left.\begin{matrix} \mathrm{O} \\ \mathrm{E}_\lambda \\ \mathrm{I} \end{matrix}\right\} \begin{matrix} \mu < \mathrm{O}, \\ \mathrm{O} < \mu < 1, \\ 1 \leq \mu, \end{matrix}$$
then
$$(\mathrm{U}f, g) = \xi \int_0^1 e^{2\pi\iota\mu} d(\mathrm{F}_\mu f, g),$$

and a trivial transformation brings this to the canonical form
$$\mathrm{U} = \int_{-\infty}^{+\infty} e^{2\pi\iota\nu} d\mathrm{G}_\nu.$$
$$= e^{2\pi\iota \mathrm{A}},$$

where A is the self-adjoint operator whose canonical expression is
$$\mathrm{A} = \int_{-\infty}^{+\infty} \nu d\mathrm{G}_\nu.$$

These two examples will suffice as illustrations of the general theory. In reviewing the book in general terms it must be said that it is an exceedingly thorough and penetrating investigation, in which no difficulty is shirked or evaded. The fundamental properties of linear operators are expounded with the utmost generality and rigour. But this is not an easy work to read. The high standard of strict mathematical accuracy which the author has set himself necessitates lengthy enunciations of his theorems and often causes the line of argument to become entangled in the intricacies of "epsilonology." It is almost necessary for the reader to peruse Stone's three original papers in order to obtain a clear bird's-eye view of the whole subject. Once the promised land has thus been viewed, he will be reconciled to a long intellectual pilgrimage before he enters into its possession. Although this is a heavy volume of more than six hundred pages, every serious student will wish that it were still longer and will await with impatience the publication of the promised supplement dealing with the *group* theory of transformations in Hilbert space.

A CENTURY IN COLOUR VISION THEORY: By Prof. W. PEDDIE, D.Sc. Being a review of **Vision and Colour Vision**, by R. A. HOUSTOUN, M.A., D.Sc., Lecturer on Physical Optics in the University of Glasgow, formerly Examiner in Physics in the Universities of Edinburgh and St. Andrews. [Pp. 238, with diagrams.] (London: Longmans, Green & Co., 1932. Price 15*s*.)

WIDER interest than at any previous time is now being taken in both the theoretical and the experimental sides of colour vision. The subject is one common to three great branches of scientific investigation—Physics, Physiology, and Psychology; and each branch is at work on that subject from its own special point of view. This has the disadvantage of a tendency towards want of unity, and, not unfrequently, towards divergence of view. But, to counter this, there has arisen a desire for mutual conference—made effective, for example, in the recent discussions held under the leadership of the Physical Society. Nothing but benefit can in consequence arise in the way of removal of ignorance or misunderstanding. And in no branch of physics has there been evident more misunderstanding regarding the development of fundamental theory. That condition still persists to some extent after the lapse of a century of endeavour.

Another source of advancement towards unity of view lies in the publication of textbooks or, more particularly, of monographs dealing with the subject. These, being written by specialists, usually advocate special views; but it is always through diversity that unity is to be reached. Dr. Houstoun's

book is of this class. He explicitly states that one object in its publication is to express his own theoretical views, and to give an account of experimental work, partly his own, which has not yet appeared in the textbooks. Thus, by implication, another object is to provide a textbook understandable by the great variety of interested readers.

When one notes the small size of the book, it becomes obvious that there must be brevity of treatment in any one part of the subject, with possibly omission or at least compression of many desirable things. It would be utterly ungenerous to dwell upon these, where they may occur, for separate opinions on such matters may be multifarious; and there can be few guides more qualified than Dr. Houston himself. He has done his work well. His treatment postulates a knowledge of elementary physics, so that elaboration in explanation can be avoided.

The first chapter deals profitably with the question of the units which are employed in the measurement of the physical quantities involved. A typical feature of the method of treatment of the whole subject appears here: no elaborate definition of adaptation is given—but its meaning is made clear. This matter is treated in further detail in the third chapter, in which the word threshold is introduced, also without strict definition; but, again, the meaning is made clear. Greater elaboration regarding the mathematical aspect of the thresholds, and the various quantities upon which their magnitudes depend, might be desirable; for there is no more vital question, involving much and difficult experimental work, in the whole range of colour vision. The third chapter also deals with structural and physiological questions.

In the second chapter intensity and its discrimination is treated. A special feature is the inversion of the usual diagrammatic representation of the least perceptible fraction of the change of intensity. Dr. Houstoun uses its reciprocal. It is to be noted, of course, that no intrinsically new information can be obtained in this way; but, as Dr. Houstoun shows, it does enable us to represent diagrammatically the least perceptible steps of sensation as equal co-ordinate steps—which is very useful. Furthermore—and this leads to one of his own special contributions on the subject—it enables us to represent the magnitude of the sensation itself by an area on the diagram. He then points out that the form of the reciprocal curve which he has introduced closely resembles a probability curve, and proceeds to make an interesting, and possibly important, application to the question of the mechanism involved in the transference of stimuli from the retina to the brain centres—which is further considered in subsequent chapters. His method gives a result in good agreement with Fechner's law within the

suitable range of stimulation. This point will be alluded to again below.

Acuity of vision and spectrum visibility are treated in the two succeeding chapters, and Newton's law of colour mixture is dealt with in the sixth chapter. In the next, the questions of discrimination of hue and of saturation are discussed; and the possible unsuitability of the test used in the former is pointed out. Exactitude could be given by Helmholtz's method modified, in accordance with Schrödinger's work, to take account of Abney's law.

Flicker and recurrent phenomena, fatigue and after-images, are the subjects of the next two chapters; while simultaneous contrast is dealt with in the tenth chapter. Here and there throughout the book experimental investigations carried out by Dr. Houstoun and his fellow-workers are described. In particular those dealing with the detailed examination of colour-blind subjects may be noted in the thirteenth chapter, along with those dealing, in the eleventh, with the distribution of colour sensitivity amongst observers who have no failing colour.

Dr. Houstoun says: "According to the original view of Helmholtz, described under his name in so many textbooks, these two classes should be the red blind and the green blind." It is too late now, except in an historical treatment of the development of the subject, to discuss the original view. To do so is useless; for it was the first, because the simplest, *tentative* assumption that was made; and subsequently discovered facts regarding colour blindness early forced Helmholtz to replace Young's simple hypothesis of *lapse* of a fundamental sensation by that of *fusion* of two—thus accounting for the condition that, in so-called red or green blindness, we have to deal with yellow-blue vision. Later, yet well on to half a century ago, he gave the fullest possible extension to the postulate—and that is the present-day position. The colour corresponding to light of *any* one wavelength may vanish. Of course, if light of that one wavelength is colourless, so also must be light of the complementary colour. There is no limitation on the localisation of the particular failing colour. Thus the trichromatic theory makes no distinction in kind as between one type of dichromasy and another. The name given to any type is merely a name conveniently expressing the colour region in which deficiency is most prominent. Thus Dr. Houstoun's conclusion from his tests is in entire accordance with the trichromatic theory. The theory can apply far beyond any hitherto observed peculiarities of vision.

The remaining two chapters of the book deal with theory, and so are more controversial. In order to understand the position accurately, we have to recognise clearly that, while we

can exactly match a colour by means of three properly selected colours taken as fundamentals, we can equally well do it by four, five, or any greater number—though not equally simply. But it is quite possible, so far as we know, that the mechanism transmits, say, four stimuli—and may do so possibly to four brain centres. The one thing that the recognised tripleness of stimuli proves is that these four transmitted stimuli, or the four central activities, *are not independent*. There must be some cross-connection or interaction which reduces the four freedoms to three effectively. This is usually implicitly, though not explicitly, recognised in the theories of multichromasy. Thus Helmholtz pointed out to Hering that his six fundamental freedoms were, because of the stated relationships, effectively equivalent to three independent freedoms only; and he wrote down the relations which enabled the transformation to the equivalent trichromatic set to be carried out.

The same condition holds with regard to the theory of Mrs. Ladd-Franklin, and to the one which Dr. Houstoun elaborates in his concluding chapter. In Mrs. Ladd-Franklin's system there are two relationships amongst five quantities, making them conduce also to three independent sensations only. And Dr. Houstoun imposes a relation on the number of fibres which are affected by two pairs of his four fundamental stimuli. But, by his relation of sensation to the number of fibres stimulated, this imposes a single relation upon the four sensations, reducing them also to three independent sensations. To say this does not detract from the real value of his system, which lies in the fact that he relates it to a definite mechanism. Mrs. Ladd-Franklin's system is similarly related. Dr. Houstoun's is quite new and most interesting, and well worthy of full consideration, especially in connection with his interpretation of the form of the sensitivity curve.

But it must be noted that certain phenomena, such as the time variation of threshold values, require explanation in a way that has not yet been developed by Dr. Houstoun in connection with his model. And it must also be remembered that Fechner's initial, and Helmholtz's fuller, treatment of the threshold variation, as due to the so-called self-light, furnishes a *single* scheme of explanation at least as adequate as that given by Dr. Houstoun. Its completeness is remarkable. Yet he (p. 28, foot) at any rate seems to imply that the trichromatic theory is tied down to the postulate that sensation is proportional to the logarithm of the intensity. All that can have occurred is that the range of applicability of that unmodified law may have been overestimated; but a test of Helmholtz's second approximation leaves little room for that supposition.

It was a most unfortunate thing that Helmholtz's great

work in advancement of the early tentative postulates remained unknown, or at least unattended to, for about a quarter of a century—even by upholders of trichromasy. To some able workers, such as Dr. Houstoun, there seemed to be in consequence certain insuperable objections to the theory, so that they turned their attention to the possibilities of multichromasy. And the resultant bias has remained with Dr. Houstoun as a deterrent, even though he has become acquainted with the advancements. He refers fully to the abandoned work, and seems to refer almost grudgingly to the developed work. And this has led him, a well-meaning critic, to misunderstanding of the basis of the theory.

He says that there is some confusion as to what the Young-Helmholtz theory actually is. To trichromatists this is not so. Helmholtz was extraordinarily careful to point out his postulates, with classification of them as essential or unessential. And Dr. Houstoun's uncertainty as to the essentialities has led him to put forward two arguments against trichromasy: (1) as opposed to common sense, and (2) as mathematically unsound. Surely such intellectual giants as Young, Maxwell, and Helmholtz might have been trusted not to enter upon unsafe territory of either kind. The first argument is that the two colour variables should be different in kind from the one intensity variable, so that the use of three variables of one type is wrong. But we can equally well represent the vector distance between two points by three length variables as by one length, and two angular, variables; and Helmholtz's investigation can be carried out in either form. Dr. Houstoun ties down the trichromatic theory far too rigidly. The issue of the third edition of Helmholtz's great work as a reprint of the first, and not of the second, edition was most unfortunate. The decision was taken with great hesitation, and apparently on the ground that Helmholtz's work on differential sensitivity was opposed to Abney's law (now known to be very accurate) and so led to a wrong conclusion. But Abney's law was non-existent when Helmholtz did that work. He had not that law as aid. Had he possessed it, he would undoubtedly have completed the problem exactly as Schrödinger has done a few years ago. But a reader of Dr. Houstoun's book might be led to conclude that Schrödinger's work was destructive of the trichromatic theory instead of being constructive towards its completion in an important direction. And that work actually enables the result to be expressed, as Dr. Houstoun desires, in terms of one co-ordinate length and two co-ordinate angles representing respectively the intensity, the hue, and the saturation. If we so desire we can take these three vectors as three co-ordinate rectangular vectors in a fresh colour-space; and so realise

Helmholtz's aim in his great attack upon the subject unaided by Abney's law.

Dr. Houstoun's mathematical argument proceeds on the assumption that sensations sum algebraically. This destroys his argument entirely: the summation is *vectorial*. In his reasoning, however, Dr. Houstoun makes another assumption, which is not essential, but leads to his wrong conclusion.

Incidentally Dr. Houstoun remarks, on the psychological aspect, that introspection may be a very unsafe guide. It only leads to postulates which may be either right or wrong, and have to be tested by non-introspective processes. That sensation can be measured is certain. The single uncertainty is with regard to a scale. One alone, as with measurement of any sensation, is available—the psychological scale of just perceptible steps, taken as equal. Variation of thresholds causes variation of these steps. It is for this reason that the investigation of threshold values is the most fundamentally important direction at present for experimental inquiry. But, in making observations, the attempt is always made to keep the thresholds constant. And measurements made under such conditions are found to give consistent results.

Measurements in terms of three standard stimuli are found to be sufficient to express all visual sensations. That is to say, any such sensation can be expressed in magnitude and quality as a function of three independent variables, taken as fundamental. We can therefore choose three of these functions as independent fundamental sensations, and express any other visual sensation in terms of them. That is the final expression of the trichromatic theory; which thus relates the measurement of sensation to the measurement of stimulus—the only two measurements which can be made of the only two observable entities.

Any fourth sensation, being expressible in terms of the three which have been selected, cannot form an independent fourth fundamental, though it may conceivably be employed for special purposes.

REVIEWS

MATHEMATICS.

British Association Mathematical Tables. Vol. II. [Pp. viii + 34.] (London: Office of the British Association.)

THE tables give the solutions of Emden's equation—

$$\frac{d^2y}{dx^2} + \frac{2}{x}\frac{dy}{dx} + y^n = 0$$

subject to $y = 1$, $y' = 0$ when $x = 0$, for $n = 1, 1{\cdot}5, 2, 2{\cdot}5 \ldots 5$. The equation is fundamental in the theory of the constitution of stars. The method of solution is due to J. R. Airey, and has been carried out by D. H. Sadler and J. C. P. Miller. The derivatives are found by differentiating the original equation, and are then used to extrapolate by Taylor's theorem. The supplementary table of Taylor coefficients at the end will have a wider application.

HAROLD JEFFREYS.

Plane Algebraic Curves. By HAROLD HILTON, M.A., D.Sc. Second Edition [Pp. xv + 390.] (Oxford University Press, 1932. Price 28*s*. net.)

THE first edition of this work on Plane Algebraic Curves was published by the Clarendon Press in 1920, and the greater part of the present edition has been reproduced by photographic processes. The book divides naturally into two parts, the first part of which, namely Chapters I–XII, forms the general introduction, while the second part, namely Chapters XIII–XIX, gives a more detailed treatment of the special properties of cubic and quartic curves. The last two chapters deal briefly with the theory of circuits and the general theory of correspondence, with special reference to the reality of the singularities of plane curves.

Prof. Hilton's work is too well known and too highly appreciated for it to be necessary for a reviewer to do more than refer to the classical position occupied by this treatise. Its characteristic features are an unparalleled wealth of examples and a generous number of illustrations of particular curves. An adequate index adds still further to the obligations of all students of algebraic geometry to Prof. Hilton. G. T.

Projective Differential Geometry of Curves and Surfaces. By ERNEST PRESTON LANE. [Pp. xi + 321.] (University of Chicago Press, 1932. Price 22*s*. net.)

THE position of projective differential geometry in a modern classification of the mathematical sciences may be defined as follows. Following Klein we now understand by a branch of analytical geometry the study of those geometrical properties which remain invariant under some prescribed group of point transformations. Thus the various branches of geometry are distinguished by their associated groups of transformations. Euclidean metrical geometry is associated with the group of translations and rotations; non-Euclidean metrical geometry with the congruence group which leaves invariant a fixed quadric (the Absolute). Affine geometry is determined by the affine

group, *i.e.* the general linear group which preserves invariant the elements of volume. Projective geometry is determined by the projective group, *i.e.* the general linear group in homogeneous co-ordinates. Finally we note that analysis situs and the geometry of the absolute differential calculus study the properties which remain invariant under any punctual transformation whatsoever.

Geometries may be further classified as integral or differential accordingly as they study the properties of an extended form or local properties characteristic of the neighbourhood of a point. It is a remarkable fact in the history of mathematics that the differential branch of projective geometry was so comparatively late in developing. The kind of property discussed in this subject may be inferred from the following elementary illustrations taken from the different branches of geometry enumerated above.

In plane metrical geometry the fundamental integral invariants of a segment of a curve are the arc-length s and the angle of contingence ψ between the tangents at its extremities. The fundamental differential invariant is the curvature $\kappa = d\psi/ds$. In plane affine geometry an invariant corresponding to the arc length may be defined as follows. If $x = x(t)$, $y = y(t)$ are the parametric equations of the curve, we can choose the parameter t so that

$$x'y'' - x''y' = 1 \qquad (x' = dx/dt, \text{ etc.}).$$

The parameter thus chosen is invariant under any affine transformation and is an integral invariant of the curve. It follows at once that there exists an invariant function $k(t)$ such that

$$x''' + kx' = 0, \qquad y''' + ky' = 0.$$

$k(t)$ is the differential invariant corresponding to κ. Thus, for the ellipse

$$x = a \cos wt, \qquad y = b \sin wt,$$

t will be the "affine arc-length" if $abw^3 = 1$. The affine curvature is then seen to be a constant, $k = w^2 = (1/ab)^{2/3}$, depending on the area of the ellipse.

In plane projective geometry it is necessary to search much more deeply for the necessary invariants. We shall use homogeneous co-ordinates, (x_1, x_2, x_3), and their non-homogeneous ratios $x = x_2/x_1$, $y = x_3/x_1$. The equation of any analytic plane curve C through the origin being written in the form,

$$y = a_1 x + a_2 x^2 + \ldots,$$

it can be shown that, with a suitable choice of the triangle of reference, the coefficients in this expression will be absolute (differential) invariants of C in the neighbourhood of the origin.

One vertex of the triangle of reference is taken to be the origin P (1, 0, 0). One side $x_3 = 0$, is the tangent to C at P. Now construct the cubic Q which intersects C at P in eight coincident points and which has a node at P. One nodal tangent of Q is $x_3 = 0$. We take the other nodal tangent to be the line $x_2 = 0$. Every nodal cubic has three collinear inflexions. We take the line of inflexions to be the line $x_1 = 0$. Finally, the scale of homogeneous co-ordinates is fixed by taking as the unit point (1, 1, 1) the point distinct from P which is common to the osculating conic K and the osculating cubic at P. The equation of the eight-point nodal cubic Q will then be $x^3 + ay^3 - xy = 0$. The conic K will be $y = x^2$, and the equation to C will be

$$y = x^2 + ax^6 + bx^7 + (b + 2a^2)\, x^8 + \ldots$$

The coefficients a and b are now absolute invariants of the curve, and in terms of these coefficients we can establish a projectively invariant classification.

The projective differential geometry of curves in space, of ruled surfaces, and of other surfaces can be developed by similar but more complex considerations. Prof. Lane wisely commences his work with the synthetic method (due to Halphen) sketched above and later introduces the more abstract researches of Wilczynski and Fubini. The whole subject is rather difficult, and the author deserves great praise for keeping geometrical realities in the foreground and for refusing to be dominated either by Lie's theory of transformation groups or Ricci's theory of quadratic differential forms. The exposition is made clearer by a fair number of diagrams, numerous examples, and a detailed index. G. T.

The Theory of Functions. By E. C. TITCHMARSH, M.A., F.R.S. [Pp. x + 454.] (Oxford University Press, 1932. Price 25*s*.)

IN the preface of this work Prof. Titchmarsh says with disarming directness that this volume consists of some rather disconnected introductions to various branches of the theory of functions both real and complex. It is true that this work does not pretend to provide a systematic account of the vast theory of functions and that it does not, therefore, compete with such treatises as those of Forsyth or Bieberbach. Nevertheless it is a most valuable contribution to the literature on the subject, and that for the following reasons.

In the first place, as regards the style in which this book is written, it may justly be compared with Littlewood's *Theory of Functions of a Real Variable*, although, needless to say, the present book bears more closely on the subject indicated by its title than does the book by Littlewood. Both books are written to supplement a definite course of lectures, to save students the labour and distraction of taking notes during the course of the lecture, and thus to allow the lecturer much greater freedom in the development and presentation of the subject. The treatment of the subject is beautifully clear and simple, the mathematics is well set out, and the book is enriched with numerous examples, many of which are drawn from recent researches in the subject.

This last remark suggests the second reason for the great value of this volume. It is that this book is evidently designed to acquaint the students as rapidly as possible with these researches which are at present being conducted in theory of functions, and to place in his hands all the tools which he will require for the initiation of his own original research. To this end a great deal of the material in classical treaties of the Theory of Functions has been deliberately sacrificed. One striking omission, which is probably explained by this object, is that of any reference to the theory of algebraic functions, or of automorphic functions. Interesting and important as these topics are, it is clear that they do not at the present day attract very many young investigators.

In drawing up this introduction to the theory of functions, Prof. Titchmarsh has had to choose very carefully among different subjects which present themselves for study. The plan of the work is as follows. After the introductory chapter on infinite series, products, and integrals, he proceeds to consider the theory of functions of a complex variable *ab initio*, and rapidly reaches the boundary of modern knowledge in the chapter on the Maximum Modulus Theorem, integral functions, and Dirichlet series. The last four chapters give an account of the theory of Lebesgue integrals, and the application of this theory to Fourier series. Probably every reviewer of this work will complain of the omission of certain branches of the theory of functions, but the author's purpose will have been achieved if the students reading this volume are thereby encouraged to study those other topics which have been unavoidably omitted from this book. G. T.

PHYSICS

The Adsorption of Gases by Solids. A General Discussion. (Fifty-sixth General Discussion organised by the Faraday Society.) [Pp. 318, with numerous text figures.] (London: The Faraday Society, 1932. Price 15s. net.)

The form in which the Faraday Society publishes its discussions must by now be so well known as to make a review of their latest publication superfluous if its purpose is merely to make known the form of the book; but if a notice of a book is in any way to be taken as a compliment, few deserve it better than this.

The choice of adsorption as the topic of the discussion at Oxford in January of this year was particularly happy, since in the previous year a number of new ideas, comprehensively described as the theory of "activated absorption," had come very much into the question, and this conference was particularly fortunate in attracting most of the protagonists of the new, and old, ideas to give their views in person. The interchange of ideas was very free and complete in the discussion which followed the usual summaries of the contributions, and was of the greatest benefit to those who were able to attend the meeting in person. This publication, which includes an account of the impromptu contributions, now confers this benefit on all those who care to buy it.

Included in this volume are forty papers, and in addition are given the discussions that followed them. They are arranged in three groups: the first, "Experimental Methods"; the second and longest on "Kinetics and Energetics"; and the last on "Theories of Adsorption." There is surely no subject which can be included under adsorption which is not mentioned. To give the names of all the contributors is not practicable, but of those which were more than summarising papers one should perhaps mention the important papers of Benton, Allmand, Taylor, and Kingman, which give the experimental evidence for the existence of activated adsorption; the papers of Lennard-Jones, Volmer, and Polanyi, which help us to explain it; the very interesting papers dealing with accommodation coefficients of Bonhoeffer and Farkas and Roberts, and several papers dealing with the experimental methods, such as those of Becker, Rideal, and Chariton Semenoff and Schalnikoff.

There can be even less chance of any effect of finality in such a production as this than in the more normal textbook, and the impression that the reviewer received at Oxford and had confirmed on reading this book was that the study of adsorption processes had entered on a new and potentially particularly productive phase. This study must be furthered by the possession of nearly all the relevant material in such a convenient form as this. Further, the conference undoubtedly produced agreement as to what was to be understood by the term "activated adsorption," so that no further misunderstandings due to a hazy nomenclature should be expected.

It might have been expected that this form of publication, which is essentially not a connected account of the subject, but a series of papers by experts, would be difficult reading, if not unintelligible to those without much knowledge of adsorption processes. This is the exact reverse of the truth, partly because of the three introductory papers that begin the different sections, and also because some of the most valuable papers are contributed by authors to whom the subject was a new one, and who, bringing fresh minds to the matter, have done much to simplify it. The Faraday Society are to be congratulated on this book, which will be of the greatest value.

O. H. W.-J.

Recent Advances in Physics.

Vol. I. **Atoms, Molecules, and Electrons.** [Pp. xii + 360, with 111 figures.]

Vol. II. **Quantum Theory.** By GAETANO CASTELFRANCHI, Professor in the High School for Engineers in Milan. Translated by W. S. STILES, Ph.D., and J. W. T. WALSH, M.A., D.Sc. [Pp. xii + 400, with 79 figures.]

Vol. III. **Non-Atomic.** By F. H. NEWMAN, Professor of Physics, University College of the South-West, Exeter. [Pp. ix. + 378, with 31 figures.] (London: J. & A. Churchill, 1932. Price 15*s*. net. per volume.)

THESE three volumes are reviewed together, as they may fittingly be regarded as a summary of recent advances in modern physics. Therefore, at the outset, we are bound to pay a tribute to the authors who have been brave enough to attempt a task of such a magnitude. In addition, we must also consider, before adversely criticising any of these volumes, how great are the possibilities of failure. It is so easy to make a disjointed patchwork of extracts from important papers, so easy to stress contributions which are not of fundamental importance, so easy to condense the accounts of experimental and theoretical researches so severely that the results are absolutely useless to the general reader, so easy to miss altogether whole branches of physics in which one has not specialised, and, finally, it is so difficult to weld into a homogeneous whole the maze of facts and theories which modern physics presents.

Consequently, it would be very remarkable indeed if a reviewer were unable to discover any flaws in these works. Again, since modern physics is here divided into atomic and non-atomic branches, some overlapping must inevitably be expected. Indeed, one feels that Prof. Newman was set a very difficult task in completing the story, for one naturally presumes that this was intended.

Personally, the reviewer is inclined to regard these volumes as convenient guide-books to, rather than treatises on, modern physics. Therefore, he is not so much concerned with the possible criticisms that condensation has in many places been too ruthlessly carried out, but he is much more concerned in noting the correctness of the sign-posts, as it were, and, therefore, in making sure that references for further reading are everywhere completely given.

For example, in the discussion of the variation of the ratio of the charge to the mass of an electron with velocity, it is stated that the cause of this variation is to be found in Einstein's theory of relativity. Here, the reviewer would recommend that some indication should also be given that the variation may be deduced from the experimental fact that radiation exerts a pressure. Again, in Castelfranchi's discussion of superconductivity, excessive condensation appears to be the cause of two extraordinary statements on p. 172, vol. ii, where the author seems to forget that heavy currents flowing in coils of wire produce magnetic fields sufficiently powerful to destroy superconductivity.

The arrangement of the subject-matter in mass-spectroscopy is rather unusual, for a discussion of the packing fraction precedes the description of mass spectrographs, and, frankly, the description of Dempster's instrument is confusing and inadequate. Castelfranchi occasionally makes a very naïve statement, such as when he advertises the work of an Italian worker on X-rays, and when he gives a reason for omitting a description of the results and technique of the Vienna workers in radioactivity.

A very good account of the theory of the Zeeman effect, and of many aspects of modern magnetism, is given in vol. II, although no reference later than that of Beck (wrongly given as 1929 instead of 1919) is given to experiments on the gyromagnetic effect. An excellent account of wave mechanics

and quantum mechanics, together with their applications, is also given, but one would like to see a better photograph of electron diffraction rings.

The faults which are to be found with Prof. Newman's book are mainly those of omission. For instance, we will consider his lists of references. We would certainly have expected some reference to E. G. Richardson's textbook on sound at the end of the chapter on acoustics. At the end of the chapter on low temperatures we are surprised that the bibliography consists of just one well-known English work on heat and thermodynamics; what about German sources of information? Again, no reference to Debye's magnificent article on magnetism in the *Handbuch der Radiologie* is to be found in the bibliography to the chapter on magnetism.

Now, the chapter on magnetism is very well written, and may be strongly recommended to students. The diagram on p. 286 should, however, be accompanied by some indication that it is not generally accepted. The reviewer is not at all sure that any simple ferromagnetic substance gives a straight line when the reciprocal of its susceptibility is plotted against temperature in the region above its ferromagnetic Curie point. Thus, Terry years ago found very definite curves in the cases of iron, nickel, and cobalt, and now we have a thesis from Strasbourg in which it is stated that a series of straight lines are obtained for iron in the β state, and even this result is not regarded as final.

Omissions are also made in the chapter on electricity, where opportunity might well have been taken to insert some valuable information on the experimental determination of dielectric constants, and where, too, the subject of atmospheric electricity might have been more adequately discussed.

These criticisms, however, can easily be met in a future edition, if, as we expect, the utility of these volumes—so excellently printed—is properly appreciated.

L. F. B.

Electrical Phenomena in Gases. By K. K. DARROW, Ph.D., Research Physicist, Bell Telephone Laboratories. (Pp. xvii + 492, with 4 plates and 91 figures.] (London: Ballière, Tindall & Cox, 1932. Price 42*s*. net.)

THIS most excellent book on electrical phenomena in gases is written in a most engaging style. One feels as if somebody had approached the author and had asked him to talk about these complicated but absorbing matters. The result is that one has the feeling that one is listening to a brilliant conversationalist the whole of the time that these pages are being perused. This is not meant to give the impression that the work is "chatty" or in any way superficial. It is meant rather to convey the idea that the reading of such a large amount of new and unfamiliar material, which would otherwise tend to be somewhat tedious, is considerably facilitated by style which the author has adopted.

For the material in this book must be regarded as new and unfamiliar, at any rate, to those who are not actively engaged in research on electrical discharges in gases. The old divisions of this subject are rapidly disappearing, the old measurements have nearly all disappeared. Thus, our fathers measured potentials in discharge tubes with probes, perhaps with feelings of despair, but at any rate often without realising in the slightest degree that they were using their probes in a most unsatisfactory manner. The Langmuir method of using probes has completely changed many of our conceptions of the electrical discharge, and, accordingly, much of the book is devoted to this method and its findings.

Again, the usual data on the mobilities of ions are absent from this book; for have not Tyndall and his collaborators spread the disquieting news that nearly all measurements of ionic mobilities are incorrect? The data must be collected anew, using gases of unheard-of degrees of purity.

Indeed, the author is so concerned with results and their interpretation that he often appears anxious not to trouble us unduly with experimental details. Perhaps he is right, but the only adverse comment the reviewer would make is that he sometimes gives the impression that he is not happy when he is describing experimental procedure.

The arrangement of his material is the outstanding feature of the book. Indeed, it is in keeping with the reputation which the author's excellent résumés in the *Bell System Technical Journal* have gained for him. He realises that the state of the gas in the discharge tube is of paramount importance, and he therefore starts with a detailed, complete account of the various processes of ionisation and of excitation and of energy interchanges between neutral and charged particles.

Then come the theory of drift, the theory of the behaviour of an ion under the influence of an electric field, and the phenomena of diffusion and recombination of ions. The author is then ready to introduce "the profounder mysteries" of ionisation by collision and the self-maintained discharge. In all cases is the available material set forth and most critically analysed and sifted. Then come the phenomena peculiar to electric fields distorted by space-charge, and these are very beautifully described, with an eye to the fact that the explanation of these phenomena will help considerably in our understanding of the luminous discharge, to which the remainder of the book is practically devoted.

The description of the phenomena occurring in the positive column is the best the reviewer has ever read, and the description of the phenomena of the cathode dark-space phenomena is also very distinguished. The reviewer, however, feels a little unhappy concerning the interpretation of the "pretty experiment" of the wheel with suitably-oriented vanes kept in continual rotation by particles stopped on their way to the cathode. The final chapter, on the arc, forms a fitting ending to the book.

The author states that he cannot flatter himself that he has mentioned everything which should find place even in a book no longer than this one. The reviewer can only say that, in his opinion, the book is one of the most interesting he has read, and that if any important investigations have been omitted, it will need a very narrow specialist to indicate them.

This book will be widely read; but it is to be regretted that its price will effectively ensure that it will be confined to the libraries of public bodies, at any rate, in England.

L. F. B.

The Theory of Electric and Magnetic Susceptibilities. By J. H. van Vleck. [Pp. xii + 384.] (Oxford: The Clarendon Press. Price 30s. net.)

The present is the third volume of the International Series of Monographs on Physics published by the Oxford University Press, the others being the outstanding works of Dirac on Quantum Mechanics and of Gamow on Atomic Nuclei. It is a first-rate production: the subject-matter is admirably presented, while the general lay-out, the typography, and paper make the book a pleasure to handle. It may be said that the whole treatise displays those indefinable but universal qualities which elevate a mere scientific text into a work of art.

The introductory four chapters are devoted to the classical theory, the remaining nine being an index to the achievements of the quantum mechanics in the fields indicated by the title. The appeal, however, is to wider interests than are suggested, and the text in general offers a readable and comprehensive survey of atomic and molecular structure. The mathematical foundations are rigorous and complete, but a first and casual impression should not be allowed to deter a reader whose mathematical equipment is small, since the various theorems and the deductions from them are in all cases

clearly stated, and stand out well from what the same reader might regard as a mathematical haze.

A delightful feature lies in the imaginative criticism of existing theories and experimental data, the references to both being up-to-date and thorough. We may cite, for example, the discussion of the various dispersion formulæ (p. 51): in the case of the CO_2 molecule we find considered the "optically inactive" fundamental characteristic of the Raman spectrum, and even a remark upon the application of Fermi's very recent work on the perturbation due to degeneracy consequent upon the coincidence of certain frequencies. Here again, as elsewhere, paucity of experimental data is indicated, and fresh fields for research are pointed out. The footnotes throughout are remarkable, and contain valuable criticisms and suggestions which, had they been incorporated in the main body of the work, would have enlarged it by another volume.

A stimulating comparison is made between the results of the classical and quanto-mechanical methods, certain of the former being rehabilitated. As an example of a case where the older fail, one may refer to the absence of magnetic susceptibility when classical Boltzmann statistics are applied completely to any dynamical system: the clear and illuminating discussion of Miss van Loeuwen's theory (p. 94) is typical of van Vleck's happy treatment of his subject. As the author points out in his preface, the use of wave functions and matrices is correlated and intermingled; the construction of the Heisenberg matrix from the wave functions by the process designated as fundamental quadrature (p. 129) is outstanding, and probably affords the best available presentation of this correlation. The use of a script type symbol for the Hamiltonian operator (necessary in distinguishing it from the magnetic field) is perhaps the one point open to criticism, inasmuch as the symbol in question hardly emphasises the prominent part it plays, and makes some of the more complicated expressions difficult to grasp as a whole on first reading.

In connection with the more general problems of atomic and molecular structure one may note the subjects of spectral notation, Russell-Saunders coupling, the Pauli exclusion principle, the exchange effect, the Kerr and Faraday effects, and Raman scattering, which are all summarised and applied. Again, as might be expected from reading van Vleck's original papers in the *Proceedings of the National Academy of Sciences* and in the *Physical Review*, the chapters on the more particular problems of dia- and para-magnetism are distinctive amongst most writing on similar subjects, in that it is possible to see what the author is driving at, and one is not left with the impression of a mass of isolated definitions and unconnected experimental data.

C. R. Bailey.

Müller-Pouillets Lehrbuch der Physik. 11 Auflage. Vierter Band. Zweiter Teil. Technische Anwendungen der Elektrizitätslehre. [Pp. xvi + 462, with 441 figures.] (Braunschweig: Friedr. Vieweg & Sohn. Akt. Ges., 1932. Price geh. R.M. 30, geb. R.M. 33.)

The huge advances in the technical applications of electricity and magnetism in recent years have made imperative the inclusion of the present volume in the eleventh edition of this famous Lehrbuch. Obviously, its scope had to be restricted to giving the physicist a general outline of the newer activities of the electrical engineer and of the new materials and appliances with which he deals, and we congratulate Prof. Siegfried Valentiner and his collaborators on the excellent results of their discriminating choice and treatment of the available body of knowledge.

Their discrimination has been such that the reader is not over-burdened with lengthy articles on constructional details of electrical machinery, but excellent pictures are given sufficiently to acquaint him with its design, and

the written descriptions are almost entirely confined to the elaboration of the physical principles on which that design is based.

Naturally, wireless telegraphy and the thermionic valve find important places in this book. The principles of action of the valve are painstakingly described, and particular attention is paid to the production of Barkhausen oscillations and to the technique of high-frequency measurements. A very good treatment of some of the modern aspects of cable telegraphy and telephony is also given, but we should have expected much more reference to the use of ferromagnetic materials of high initial permeability in cable work, in view of the huge amount of research on these materials which the cable companies appear to encourage.

L. F. B.

The Interpretation of the Atom. By Prof. F. Soddy. [Pp. xx + 355, with 73 illustrations and 2 folding charts.] (London: John Murray, 1932. Price 21*s*. net.)

This work is eminently suitable for the general reader who seeks an insight into the phenomena of radioactivity and their bearing upon the development of chemical knowledge. Indeed, Prof. Soddy presents an extremely well-written account of the modern aspects of chemistry, which is well illustrated and delightfully easy to read. There is a little misstatement on p. 283, where it is recorded that for accurate counting by the scintillation method not more than three or four α-particles must strike the screen per minute; it is easy, of course, to deal with thirty per minute.

L. F. B.

The Classical Theory of Electricity and Magnetism. By Max Abraham, formerly Professor of Rational Mechanics at Milan, and revised by Richard Becker, Professor of Physics at the Technische Hochschule, Berlin. Authorised translation by John Dougall. [Pp. xiv + 285.] London: Blackie & Son, Ltd., 1932. Price 15*s*. net.)

The present volume is a translation of the eighth German edition of Max Abraham's well-known work. Vector notation is employed throughout, but, of course, it has been modified in the translation to make it conform to English usage. It is a volume which must command the serious attention of all teachers of advanced physics, for it is compact, contains little superfluous matter, and really makes an attempt to give the reader a proper grasp of the more difficult theoretical aspects of electricity and magnetism. This attitude is particularly to the fore in the discussion of the dielectric constant, where, incidentally, the reviser might have seized the opportunity to put in just a few words about the theoretical treatment of polar molecules.

A pleasing feature of the book is the collection of examples—with answers and hints—at the end. They are headed by the quotation, " But be ye doers of the word, and not hearers only, deceiving your own selves—James i, 22." It is nice to realise that in physics the need of doers is for once admirably recognised.

L. F. B.

Physics. For Students of Science and Engineering. Seventh Revised Edition. Edited by A. Wilmer Duff. [Pp. xiv + 681, with 630 illustrations.] (London: J. & A. Churchill, 1932. Price 18*s*. net.)

This is a very pleasing textbook of physics brought up to date in this seventh revised edition by the collaboration of six well-known American physicists. It is approximately of that standard which in England is termed intermediate. The subject-matter is simply and clearly presented without superfluity of expression or of reiteration, and with very little duplication, in spite of the number of contributors.

The fact that this is the seventh edition—the first appeared in 1908—and

that the sixth edition has recently appeared in China, complete, except for the name and address of a publisher, is sufficient evidence of its soundness.

L. F. B.

The Structure of Molecules. By P. DEBYE, Professor of Experimental Physics in the University of Leipzig. Translation by WINIFRED M. DEANS. [Pp. xii + 190, with 5 plates.] (London: Blackie & Son, 1932. Price 15*s*. net.)

THIS volume is the latest of that excellent series of translations of the discussions which now appear to be a regular feature of the scientific life of Leipzig; they owe their existence, of course, to the immense activity of Prof. Debye, who edits the volume.

The particular discussions here published took place in 1931, and they are confined to problems of molecular structure. Thus K. L. Wolf discusses the problems of rotation about single and double carbon bonds, whilst R. Miecke discusses molecular vibrations as revealed by band spectroscopy. Their contributions are supported by F. Rasetti's paper on the Raman effect in crystals, and by G. Placzek's summary of the relationship between the intensities of the scattered lines and the symmetry of the molecular structure of the scattering material, and by his explanation of the polarisation of the scattered radiation.

Miss H. Sponer deals with the dissociation of molecules under the influence of light, whilst V. Henri deals with what is termed predissociation, and what is identified by the occurrence of blurred-band spectra. These blurred bands R. de L. Kronig considers to be due to radiationless transitions of the molecule to continuous energy levels, and he lays down a number of rules for their occurrence. Finally, the whole question of the electronic structure of molecules is discussed by G. Herzberg.

The book is, as usual, excellently printed and illustrated. L. F. B.

Tables of Cubic Crystal Structure. By I. E. KNAGGS, B. KARLIK, and C. F. ELAM. With a Foreword by Sir WILLIAM BRAGG. [Pp. 90 + blank pages for notes.] (London: Adam Hilger, Ltd. Price 11*s*. 6*d*. net.)

IN compiling this little volume of X-ray crystallographic data of the cubic system the authors have taken a valuable share in shouldering one of the principal tasks of modern structural research, that of replacing, or rather supplementing, existing collections of crystallographic data, such as the well-known *Chemische Kristallographie* of Groth, by corresponding tables of absolute dimensions and atomic co-ordinates in the space-lattice. The *Strukturbericht* of Ewald and Hermann is still the most heroic and comprehensive effort of this kind, but for such purposes as chemical analysis by X-rays, facilitated by devices such as the "Hilger Crystallograph" and interpretive chart, the present tables of cubic data should prove extremely useful, especially as they contain more recent results not contained in the *Strukturbericht*. Drs. Knaggs and Karlik have dealt with elements and compounds, while Dr. Elam has contributed a section on alloys. For 513 substances of the former class and 156 of the latter we are given the composition, space-lattice, lattice dimensions, and critical remarks, all arranged in a highly convenient form, while, of course, the list of actual literature references (over 900 just for the cubic system alone!) is intended to be exhaustive. The authors are to be congratulated on the successful completion of a task which there is a very natural tendency to shirk, and Messrs. Hilger on another useful addition to their now extensive series of publications.

In the Introduction (third line from the end) the letter S, as the international symbol for a simple lattice, should be replaced by P (primitive), and reference 107, p. 56, should read W. H. Bragg instead of W. L. Bragg.

W. T. ASTBURY.

Time, Matter and Values. By Professor R. A. MILLIKAN, Ph.D. [Pp. x + 99, with 14 figures on plates and in the text.] (London: Oxford University Press, 1932. Price 6*s*. net.)

THIS little book contains the substance of the McNair lectures delivered by Prof. Millikan to the students of the University of North Carolina. It contains a broad survey of the development of our ideas relating to time and matter during the past three hundred years and concludes with a simple and sincere exposition of the author's faith in God. The historical aspects have been simplified so that the main facts stand out clearly in logical sequence, and the lectures must have been ideally suited to an audience of serious young people engaged in studies in which landmarks are only too likely to be obscured by masses of detail. Unhappily such students often find it a strain to purchase essential textbooks, and one cannot ask them to pay 6*s*. for a hundred pages on each of which the pleasantly large print occupies only $4\frac{1}{4} \times 2\frac{1}{4}$ inches. A pity indeed!

D. O. W.

Modern Physics. By G. E. M. JAUNCEY, D.Sc., Professor of Physics, Washington University, St. Louis. [Pp. xvii + 568, with 213 figures in the text.] (London: Chapman & Hall, 1933. Price 22*s*. net.)

THIS book is published in the United States and is described by its author as a second course in college physics. It is, in fact, the first book to contain a considerable account of twentieth-century developments in physics treated *academically* in a manner well within the scope of the pass student. It is therefore a very remarkable achievement. The subject-matter is largely, but not exclusively, electrical. On the electrical side there are chapters on alternating currents, the electro-magnetic theory of radiation, the electron, thermionics, photo-electricity, X-rays, the Bohr theory, critical potentials, radioactivity, and electrical resistance. In addition there are others on geophysics, astrophysics, the kinetic theory, relativity, specific heats (including Debye's theory), supersonics, and the old and new quantum theories. Numerical problems are appended at the end of most of the chapters, answers being given at the end of the book. With all this the author has found it possible to devote thirty-four pages to an historical survey of physics, another twenty-five to an exposition of the calculus, and others to photographs of, *e.g.*, A. H. Compton and Werner Heisenberg. Much, of course, has been omitted, but the author knows how to teach, his treatment is scientific and not semi-popular, and his book is one which can be recommended without reserve to both teachers and students of physics.

D. O. W.

The Method of Dimensions. By ALFRED W. PORTER, F.R.S., Emeritus Professor of Physics in the University of London. [Pp. vii + 78, with 9 diagrams.] (London: Methuen & Co., 1933. Price 2*s*. 6*d*. net.)

THIS is the second volume which Prof. A. W. Porter has contributed to the admirable series of monographs on physical subjects edited by Dr. B. L. Worsnop. The subject is one to which he has devoted considerable attention, and he is able to illustrate its application in many branches of physics by reference to his own work or to that of his students. The book is divided into seven short chapters. The first contains an historical account of the method and, by way of illustration, its application to the simple pendulum. There is, however, no clear statement as to what is meant by dynamical similarity. Chapter II deals with the flow of fluids and contains an account of Lees' reductions of the observations of Stanton and Pannell on the flow of water and air through pipes, and of turbulent flow past obstacles. Chapter III is concerned with surface tension; Chapter IV with vibrating systems, and Chapter V with heat and temperature (but without any

reference to the work of Rayleigh and Davis on convection). Electricity and Magnetism are disposed of rather summarily in the five pages of Chapter VI, and the book closes with a brief discussion of the position of mass considered as a fundamental entity.

The only comparable treatment of the subject published recently in this country is the much shorter one written by Prof. Levy for the *Dictionary of Applied Physics*. Few pockets, however, can provide a *Dictionary* and still fewer can house its first volume with any comfort. Professor Porter's book is conveniently designed for all.

D. O. W.

An Introduction to Applied Optics. Vol. II. Theory and Construction of Instruments. By L. C. Martin, D.Sc., Assistant Professor of Technical Optics, Imperial College of Science and Technology, London. [Pp. viii + 289, with a frontispiece, 1 plate, and 211 figures in the text.] (London: Sir Isaac Pitman & Sons, 1932. Price 21*s*. net.)

The merits of the first volume of Dr. Martin's *Introduction to Applied Optics* are now well known, and in the volume under review he proceeds in the same style to consider the fundamental optical instruments, *i.e.* the telescope, microscope, and photographic objective. Chapters devoted to these subjects, together with two others on the photometry of optical systems and the testing of optical instruments, form substantially the whole contents of the book. The treatment throughout is comparatively simple and well suited to the needs of the student of physics who desires to know something of the realities of optical design but has no immediate intention of putting his knowledge to practical, or rather commercial, use.

One chapter which should be consulted by every student is that dealing with the photometry of optical systems, for the treatment in all other books is quite inadequate considering the importance of the subject. The discussion here is very clear, and one can only regret that the examples given do not include that most familiar of all optical systems—the galvanometer mirror with its lamp and scale. Included in the book is a short list of errata in Volume I—one of them quoting the expression in that volume incorrectly!

Those who have already added the first volume to their library will naturally purchase this, and they will not be disappointed. Others, making their first acquaintance with the author's treatise through its concluding part, will appreciate the desirability of owning the whole.

D. O. W.

The Principles of Optics. By Arthur C. Hardy, M.A., Associate Professor of Optics and Photography, Massachusetts Institute of Technology, and Fred. H. Perrin, S.M., Instructor in Physics, Massachusetts Institute of Technology. [Pp. xiii + 632, with 319 figures in the text.] (New York and London: McGraw-Hill Publishing Co., 1932. Price 36*s*. net.)

This book is issued as a volume of the *International Series in Physics* edited by Prof. F. K. Richtmyer, and is quite unlike any other book on the subject printed in the English language. The avowed purpose of the authors is to fill the gap between textbooks of the rigidly scientific type and those devoted exclusively to technical matters such as optical design, colour measurement, or ophthalmics. This end has been attained by a treatment which is largely descriptive; mathematical formulæ are quoted whenever necessary, but the proofs are generally omitted, especially when they are long or difficult. In this way room has been made for a vast amount of information which usually remains quite unknown to the university student. The book is quite definitely one which should find a place in all college libraries.

An initial chapter devoted to fundamental concepts is followed by six others dealing with "geometrical" optics, including aberrations, the theory

of apertures, and resolving power. Next comes a section of seven chapters which might be titled Photometry: the successive headings are Radiation, Light Sources, Eye, Photography, Light-sensitive Cells, Photometry, and Colour. These are followed by sixty-odd pages dealing with optical materials (including, of course, optical glass) and the manufacture and testing of optical parts. Chapters XIX–XXVII are concerned with optical instruments of *all* kinds, and finally there are two chapters devoted to interference and polarisation. Subjects of mainly theoretical interest such as spectrum analysis, electro-magnetic theory, and the Raman effect are omitted; books dealing with them are readily accessible, while much of the information given here is otherwise available only in technical papers which the average student of pure science has neither time nor opportunity to consult.

It only remains to add that the authors have a thorough and up-to-date knowledge of their subject and that much of the book can be read in an arm-chair without the aid of pencil and paper.

D. O. W.

Physical Principles of Mechanics and Acoustics. By R. W. POHL, Professor of Physics in the University of Göttingen. Translated by WINIFRED M. DEANS, M.A., B.Sc. [Pp. xii + 338, with 13 plates and numerous figures in the text.] (London: Blackie & Son, Ltd., 1932. Price 17*s.* 6*d.* net.)

THIS book contains all the originality in experiment which the author's companion volume on the *Physical Principles of Electricity and Magnetism* has lead us to expect from him, and we are glad to learn that a third volume on *Heat and Light* is to follow. Unfortunately the theoretical treatment is equally unorthodox, and the reviewer is of the opinion that, helpful as the book will undoubtedly prove to teachers seeking apt illustrations for their lectures and experiments for their laboratories, it is quite unsuited for use as a *class-book* for English students *unless* they have already received a thorough training in the fundamental principles of mechanics. The definitions of force and mass and, even more, the systems of "continental" units described on pp. 34–37 seem particularly unfortunate. Points of this kind are, however, of small importance compared with the freshness of the treatment of the subject once these elementary (but controversial) points are passed. With so much that is novel it is difficult to make a selection of any particular points, but it may be suggested that anyone looking over its pages at his bookseller's to test its worth should glance through Chapter VIII on Accelerated Systems of Reference and Chapter XI on Vibrations—unless, indeed, it is desired to avoid a purchase!

D. O. W.

Wave Mechanics (Elementary Theory). By J. FRENKEL, Professor at the Physico-Technical Institute, Petrograd. (Oxford: at the Clarendon Press. Volume I, 1932. Price 20*s.*)

THIS book is the first of three volumes forming a comprehensive treatise on Wave Mechanics. Each volume is complete in itself, and the present volume is introductory to the whole subject, being entirely devoted to the elementary theory. These three volumes by Prof. Frenkel are an expansion of his well-known work *Einführung in die Wellenmechanik*. The difficulty which Prof. Frenkel has set himself to solve is to bridge the gap between Classical Physics and the Quantum Theory. The method of solution which he has adopted, in common with many other writers on the subject, is to introduce the subject of Wave Mechanics by a detailed comparison of the corpuscular and undulatory properties of light and matter. This method is probably the best for a student who is already imbued with ideas of classical physics, although it is to be hoped that future generations will be able to study the quantum theory directly without the intervention of classical theories. The first two chapters

of this book develop in some detail the parallelism between the corpuscular and wave theories of light and matter. An original observation due to the author is that Newton's theory of " Fits of Reflection and Transmission," viewed in the light of our present knowledge, seems to be an anticipation of the principle of indeterminacy. It is characteristic of Frenkel's work that he stresses very strongly the analogy beween waves of light and probability waves of the quantum theory. In fact it appears from some statements made in these introductory chapters that the author regards these waves of probability not merely as convenient mathematical concepts but as physical entities, having as real an existence as waves of light and sound. The truth of the matter is, of course, that the wave functions of the quantum theory are simply the components of certain vectors defining quantum states, and that the picturesque form of the theory which results from endowing these waves with physical reality is simply a confusion of mathematical technique with physical reality.

This confusion has led the author to the unfortunate misunderstanding of Heisenberg's theory of the " Uncertainty Relations " and Dirac's general theory of Quantum States. The following quotation exemplifies Frenkel's general attitude:

" Equally misleading is the expression which is becoming current that the observer ' prepares ' the system which is to be considered. This ' preparation ' is again a logical process and not a physical process produced by the observation."

It is quite clear from these two sentences that the author has not appreciated the fundamentals of Dirac's treatment of the quantum theory. This theory, which is simply a summary statement of standard experimental procedure in micro-physics, consists essentially in the principle that we only know that a micro-physical system has a certain characteristic when we have just impressed that characteristic upon the system by passing it through a suitable apparatus. The " preparation " of a physical system is essentially a real physical process by means of which certain characteristics are impressed upon the system, as, *e.g.*, when silver atoms are passed through an inhomogeneous magnetic field and then emerge with quantised magnetic moments.

Chapter III of Frenkel's book gives an account of the standard simple examples of the wave mechanics of a particle in a field of force. The usual examples are given, *i.e.* the reflection and transmission of waves through a potential discontinuity, the harmonic oscillator, and the hydrogen atom.

The same chapter also gives an account of the method of the " Protential Staircase " which has been used by Hill, Krönig, and Penny, and a brief account of the work of Gamow, Gurney, and Condon.

Chapter IV deals with wave mechanics of the system of similar particles and develops the symmetry properties of the wave functions and the Pauli exclusion principle.

The remaining two chapters do not, strictly speaking, form part of the subject of Wave Mechanics, but they are almost indispensable to a proper understanding of the quantum theory of gases and the electrons in metals.

Chapter V gives a summary of statistical mechanics with particular regard to the quantum distribution laws.

Chapter VI is mainly concerned with the theory of the electron gas and the theory of electrons in metals. The quantum theory enters here only in the enumeration of the number of " Complexions." Frenkel has given an account of his own simplified method of discussing the conductivity of metals, and the book closes with an account of the theory of a gas composed of Phonons (quanta of sound) and the theory of a gas composed of Photons. There is unfortunately no index.

It is a little difficult to review an introductory work of this kind prior to the publication of the remaining two volumes of the complete treatise. It is,

of course, an admirable summary of all the phenomena which can be treated by the elementary methods of Wave Mechanics. The deliberate insistence on the waves as physical entities does seem to obscure to some extent the real significance of the quantum theory. It also seems unfortunate that this treatise should take its title from what is now an exploded analogy or at best a mathematical technique.

G. T.

CHEMISTRY

Chemical Analysis by X-Rays and its Applications. By G. VON HEVESY. [Pp. 333, with 101 figures.] (London: McGraw-Hill Publishing Co., 1932. Price 18*s*. net.)

PHYSICS has a tendency to bear offspring which rapidly grow, leave the fold, and set up as sciences on their own account. One of the latest claimants to independence is X-ray analysis. Prof. von Hevesy was one of those distinguished sponsors, including Moseley, Darwin, and Bohr, associated with Rutherford at Manchester, who had much to do with the newcomer's birth. Since then he has taken a notable part in its upbringing, and is well qualified to describe its present stage of development, especially in that aspect concerned with chemical analysis.

The book is based on lectures given at Cornell University during his tenure of the George Fisher Lectureship in Chemistry, and is dedicated to Moseley. The first part deals with theory and technique; it suffices for an intelligent appreciation of the potentialities, as well as the difficulties, inherent in the detection and estimation of an element by means of its X-ray spectrum. The chapter on measuring the intensities of X-ray lines is a helpful addition to the usual description of X-ray tubes and apparatus. Another feature worthy of note is the series of comprehensive tables which are appended to Part I. We note that Prof. von Hevesy still considers, and rightly, we think, that Laby's estimate of the sensitivity of the method is too high, although he hopes that some day, with improvements in technique, it may be too low.

The second and third sections of the book particularise. The experiments which led to the discovery of hafnium, and the properties of the element, are set forth in detail. The determination by means of X-ray spectroscopy of the abundance of the sixty rare elements in igneous rocks is discussed very fully. Many physicists will learn with pleasurable surprise of the powerful way in which X-ray methods have been applied, in this connection, by the chemist. The relative abundance of the elements, the chemical composition of the solar system, and the ageless problem of the age of the earth are then treated in the light of a wealth of data.

The book is illumined in parts by flashes of interesting memories. These, and the wide range of subject-matter, should make an attractive appeal, not only to the specialist, but also to the more general reader.

W. A. WOOD.

Perfumes, Cosmetics, and Soaps, with Especial Reference to Synthetics. By W. A. POUCHER, Ph.C. Vol. II, Fourth Edition. [Pp. xv + 599, with 57 plates and colour-chart inset.] (London: Chapman & Hall. Price 30*s*. net.)

THE publication of this volume so soon after the appearance of the former edition in 1929 is evidence of the increased interest now being taken in this country in that branch of applied chemistry which is concerned with the production of perfumes and cosmetics.

The work is divided into two volumes. The first, of which the latest edition (the third, published in 1930) was reviewed in SCIENCE PROGRESS in October, 1930 (vol. xxv, No. 98, pp. 344–5), is a dictionary of raw materials.

The second volume is of a practical character, and treats of the manufacture of the majority of those types of perfumes and cosmetics in demand to-day.

The book is divided into two parts, one devoted to Perfumes, the other to Cosmetics. As the scope of the work is well known to all perfume and cosmetic chemists, it will suffice to indicate here the additions which have been made in the present edition. The most important, perhaps, are those to be found in the chapter on "Soap Perfumery." Under the name of each type of odour, a classified list of the components which may be usefully employed is given, as well as a selection of typical formulæ.

Other additions to this Part include short monographs on Chypre and Gardenia perfumes, a selection from published sources of Continental formulæ for the production of Chypre and Lilac perfumes (types which are now very popular), and a new chapter on "Fruit Flavours."

In the second Part, a number of alterations in the formulæ will be noted, and there are short sections dealing with cholesterol hair lotions, skin varnish, and other modern products. Another novelty is the inclusion of a colour chart, by Mr. Reco Capey, A.R.C.A., showing a number of colours, distinguished as "pigments," "tints," and "shades," which the author considers suitable for lipsticks, face-powders, and rouges, eyelid shadows, and eyelash pencils respectively

Altogether, the new edition of Mr. Poucher's work is a decidedly useful volume, which every chemist interested in the perfumery and cosmetic industries will desire to place on his library shelves.

H. S. REDGROVE.

Explosives, their History, Manufacture, Properties, and Tests. By A. MARSHALL, F.I.C. Second Edition, vol. III. [Pp. xvi + 286, illustrated.] (London: J. & A. Churchill, 1932. Price 42*s*. net.)

THE first two volumes of this well-known treatise were published in 1917, and the present, third, volume has been produced mainly with the idea of bringing the earlier volumes up to date by including in it references to the great amount of information that has become available since the Armistice; to enhance its usefulness the third volume has a complete index to the whole work, comprising about 4,300 entries.

For this reason the present volume is necessarily somewhat "scrappy," as its purpose is not to provide a textbook but a reference work to recent developments. The 40 short chapters are subdivided into 12 sections: historical, black powder, acids, nitric esters (solid and liquid), nitro compounds, smokeless powders, blasting explosives, properties of explosives; special explosives such as service explosives and coal-mine explosives, stability, materials, and analysis, with an appendix giving the regulations of the German Railway Commission, and five pages of thermochemical data. (In passing, the paragraph upon Cuprene on p. 227 might be somewhat expanded in view of the number of patents issued for its production and use.) It will be seen therefore that the ground is well covered, and those chemists and laboratories which already possess volumes I and II will be well advised to complete these by acquiring the present volume, which reflects great credit upon author, printer, and publisher.

F. A. M.

New Conceptions in Biochemistry. By N. R. DHAR, D.Sc. (Lond. and Paris), M.Sc. (Cal.), F.I.C., Professor in the Chemistry Department, University of Allahabad. [Pp. x + 165.] (Allahabad: The Indian Drug House, 1932. Price 7*s*. 6*d*. net.)

THE author states in the preface that in this book, which comprised a course of lectures delivered by him in the Patna University, an effort has been made to discuss the general physico-chemical aspects of biochemistry which have

any bearing on metabolism. The main thesis of the book is that many diseases are due to lack of proper and balanced oxidation of fats, carbohydrates, and proteins, and that exaggerated oxidation of one or other of these three classes of food materials in preference to the other two may lead to the incidence of several diseases. The author states it as his opinion that biological oxidations are induced reactions, and that there exist in the animal body readily oxidisable substances, such, for example, as glutathione, the oxidation of which induces the oxidation of, say, sugars and fats, while the oxidation of proteins may result from catalytic reactions at surfaces as illustrated by Warburg's oxidation of amino-acids on the blood charcoal model; he is of opinion that a case has been made out in support of the view that iron preparations, mild alkalis, phosphates, vitamins, internal secretions and light act as accelerators in the oxidation of food materials. The book makes quite stimulating reading, and contains a number of suggestions which, even if not accepted as proven, give food for thought; on the whole the author gives quite a good account of the more recent contributions to biochemical knowledge, though he is, perhaps, little inclined to stress the reference to his own published papers.

P. H.

A Course of Practical Work in Agricultural Chemistry for Senior Students. By T. B. Wood. New Edition, revised by H. H. Nicholson. [Pp. 56.] (Cambridge: At the University Press, 1932. Price 2*s.* 6*d.*)

This well-known little manual has reissued in substantially the same form as before; this has been effected by the removal of certain portions of the original text and replacing them by new paragraphs dealing with the modern method of mechanical analysis, with the estimation of nitrates in soils and fertilisers, and with the lime status of soils—exchangeable lime, etc. Thus brought up to date the book should enjoy a further period of usefulness and popularity.

P. H.

GEOLOGY

Geophysics, 1931. Being Transactions of the Society of Petroleum Geophysicists, Vol. I. Published by The American Association of Petroleum Geologists, Tulsa, Oklahoma, U.S.A. [Pp. iv + 113.] (London: Thomas Murby & Co. Price $2.50.)

This publication consists of a set of seven papers on the application of geophysics to the location of mineral deposits. The papers were presented at the annual convention of the American Association of Petroleum Geologists at San Antonio, March 21, 1931. They were contributed by practising geophysicists with the objective of summarising many of the problems which have recently arisen in the United States, and indicating the method of attack evolved and the degree of success attained. Within the last two or three years, the difficulties of locating fresh deposits of petroleum in the United States have grown very considerably. Most of the shallow salt-dome producers have been found and tapped, and the search must now proceed among more complex structures which present complicated problems to the geologist and the geophysicist. Every refinement of instrumental development and analytical technique of operation and interpretation of the results must now be at the disposal of the geophysicist.

Of the seven papers, two deal with the gravitational method of geophysical prospecting, two more are concerned with the seismic method, and the remaining three with the magnetic method, which last is a recognised preliminary to the previous two in dealing with suitable structures. D. C. Barton discusses the torsion balance survey of the Belle Isle salt dome, and shows how

a fairly correct estimate was made of the extent and distribution in depth of the cap rock of this dome. The predictions were subsequently verified by borings. R. H. Miller describes the torsion balance results obtained in the Los Angeles basin, in the vicinity of an oil-field, and shows how they may be interpreted to indicate the increases and decreases in density in individual geological strata due to compressions and rarefactions arising from folding. This author stresses the inadvisability of assuming that a loosely consolidated bed, *e.g.* of sand, has a uniform density.

E. McDermott gives a very clear review of the modern method of seismic prospecting by "reflection," as distinct from the older "refraction," type of "shooting." The refraction method was a prolific locator of shallow-seated salt domes, but fails when deeper or more complex structures are in question. The reflection method involves a considerable refinement in instrumental capacity and analytical technique. On the other hand, B. McCollum and Wilton W. La Rue show how the presence of existing wells may be an important factor in extending the scope of refraction shooting, since these wells can serve as sites of varying depth for recording seismographs of suitable design.

E. D. Lynton describes the results of some test magnetometer surveys in California over typical structure, *e.g.* an anticline, a syncline and a buried fault. W. M. Barret calculates the effect on a geomagnetic survey of a buried well casing, which is magnetised by induction under the influence of the earth's magnetic field. This author shows how disturbing magnetic components, of magnitude comparable with those of the anomaly sought, may arise in the vicinity of such a casing. J. H. Wilson describes a simple Brunton compass attachment for measuring the horizontal component of the earth's field with an accuracy sufficient for reconnaissance surveys.

The papers which form this set of transactions should prove of considerable value to practical geophysicists in other countries, since the equipment and methods described are of very general application. Geologists and mining engineers will also welcome the fullness of detail and clarity with which the geophysicists present their problems and solutions. The papers are for the most part free from abstruse mathematics and technicalities, but are in no degree "popular."

E. LANCASTER-JONES.

Metallurgy. By EDWIN GREGORY. [Pp. xviii + 284, with 188 figures.] (London: Blackie & Son, Glasgow. Price 17*s*. 6*d*. net.)

THIS is an elementary textbook on metallurgy for engineers. Parts of it are so good that it is a pity that other parts have been spoiled by trying to compress too much into too little space.

Chapters 1 and 2 contain a skilfully condensed description of the iron- and steel-making processes (some sections of which are perhaps just too much condensed to be easily intelligible to anyone unfamiliar with the subject), and an interesting and useful account of the various products. This is followed by a chapter on the constitution of metallic systems, which would have to be considerably enlarged to make it really useful. The next three chapters, which occupy nearly half the book, describe, from the theoretical and practical standpoints, the heat-treatment, properties, and uses of carbon steels, structural alloy steels, and special alloys, such as high-speed steel and stainless steel. As would be expected from the fact that the book is a Sheffield product, and that the author has had considerable practical experience of steel making, these chapters are excellent. They alone are well worth the cost of the book. The remaining chapters deal interestingly, but too briefly (considering the comprehensive title) with the common non-ferrous alloys.

The book can be recommended as a good introduction to metallurgy for engineers, especially for those interested in the ferrous branch of the subject.

In many ways it is superior to others of its class—the diagrams and micrographs with which the text is illustrated, are, for example, genuinely instructive and not merely ornamental. The only real fault of the book is the brevity with which parts of the subject are dismissed.

M. S. Fisher.

BOTANY

The Medicinal and Poisonous Plants of Southern Africa. By Prof. J. M. Watt and Dr. Maria G. Breyer-Brandwijk. [Pp. xx + 314, with 12 plates in colour and 14 in black and white.] (Edinburgh: E. & S. Livingstone. Price 25*s*. net.)

This work, which should prove a valuable book of reference, treats of the poisonous South African plants, and those known, or believed, to have medicinal virtues, arranged in their respective families. Details are furnished as to the chemical nature of the essential substances that have been isolated, and also such information as is available regarding their pharmacological and poisonous effects.

The authors point out that the native medicinal lore is extensive, but is rapidly vanishing, and hence in these pages they have attempted to record the facts regarding the folk-medicine of South Africa whilst the data are still available. Some of these native remedies are probably of little, if any, use, as for example the native "cancer cure" by the use of *Sutherlandia frutescens*; trials with which have proved negative. To stamp out an epidemic of colds the Sutros utilise an infusion of *Aloe latifolia*, in which the entire population of the village must bathe in public. But if some, such as these, scarcely appear to warrant inclusion in the official *Pharmacopœia*, there are others which are efficient and sometimes even drastic, such as the purgative obtained from the seed of *Jatrophe curcas*, the efficacy of which is attested by the native name of "Hell Oil."

There are numerous poisonous plants in South Africa which are the cause of serious losses to farmers such as *Urginea* spp., *Ornithogalum glaucum*, *Crotalaria* spp., *Tribulus terrestris*, *Dichapetalum cymosum*, *Cynanchicum africanum*, and *Geigera* spp. But there still remains much work to be accomplished in filling in the gaps of our knowledge. The relation of toxicity to habitat is a promising field for investigation, as is shown by the fact that the fruits of *Solanum nigrum*, which are poisonous in Europe, are eaten with impunity in S. Africa, whilst the effect of soil is witnessed by the much higher toxicity of *Cotyledon orbiculata* when growing on the clayey soil of the Magaliesberg than when growing in the sandy soil of Onderstepoort. The effect of burning veld is often to render certain toxic species relatively, if not absolutely, more abundant, with a consequent increase in cases of poisoning, but this aspect of the successional ecology has as yet scarcely been studied.

It is obvious, in turning over the pages of this work, how much remains to be done in this field, and the authors have rendered a distinct service to pharmacology in bringing together existing data and thus rendering evident the numerous lacunæ that await filling.

E. J. Salisbury.

Cacao. By Dr. C. J. J. van Hall, late Director of the Institute for Plant Diseases, Buitenzorg. Second Edition with illustrations. [Pp. xviii + 514.] (London: Macmillan & Co., 1932. Price 28*s*. net.)

For the benefit of readers not familiar with the first edition of this book which appeared in 1914, it should be stated that it was written with a view to emphasising the practical aspects of the subject. It is admitted by the author that practical planting work can only be learned in the field, but in his opinion many practical men know how to act to get the best result without knowing

the reason for their action; it is this deficiency which the book is intended to supply. Since the first appearance of the book, however, views about the cacao plant and its culture have undergone considerable modification, and this has necessitated making extensive alterations in many chapters. The book, which is profusely illustrated, is divided into twenty-one chapters dealing with a large variety of aspects of the subject, such as geographical distribution, the chemistry of the cacao, botanical characteristics of the plant and its varieties, cultivation of cacao, selection, fermentation, and washing, etc. Diseases and enemies form the subject of one chapter, which has been much enlarged; an interesting account is given of the combating of the bugs which attack the plant by means of ants. Another chapter which has had considerable additions made to it is one dealing with methods of culture adopted in the various cacao-producing countries. The book is well produced and very readable, and contains a wealth of information which will be much appreciated by those in quest of enlightenment on almost any aspect of the subject of the cacao plant and its cultivation.

P. H.

ZOOLOGY

Recent Advances in Cytology. By C. D. DARLINGTON, D.Sc., Ph.D., with a Foreword by J. B. S. HALDANE, M.A., F.R.S. [Pp. xviii + 559, with 8 Plates, 109 Text-figures, and 66 Tables.] (London: J. & A. Churchill, 1932. Price 18*s*. net.)

THE title of this book is rather misleading, for it is concerned exclusively with that special branch of cytology which deals with the nucleus and only mentions the cytoplasmic structures when they have a direct bearing on nuclear phenomena. It should, as Mr. Haldane remarks in the foreword, be called a treatise on Karyology. The subject of nuclear cytology has attained its present prominence and importance largely on account of its close relation to genetics. It is, however, a separate study which, as Dr. Darlington points out, rests "on its own postulates and using its own technique . . . provides an independent tool for the investigation of heredity, variation, and evolution." During recent years the subject has advanced with extraordinary rapidity, and its methods have become quantitative and analytical rather than purely descriptive. In this book the author's treatment of his subject-matter is frankly critical, and often involves long chains of deductive reasoning. Those who read it expecting to find in it merely a summary of recent descriptive cytology may well be surprised to find that this branch of morphology has already become a largely deductive science. In consequence those unaccustomed to the deductive method will find it difficult reading.

The book provides a masterly review of an immense amount of recent literature on nuclear cytology in both plants and animals, some idea of the extent of which can be gained from the fact that the bibliography contains about a thousand references. The author's clear and logical style, and the numerous figures and diagrams in the text do much to mitigate the inherent difficulty of the subject. The last chapter is devoted to a theoretical discussion entitled, "The Evolution of Genetic Systems." In it the author develops his own views, which are stimulating and amazingly interesting, though difficult to digest and highly theoretical. The value of the book is further enhanced by the inclusion of Appendices on "Cytological Interpretation," Recent Improvements in Technique," and a "Glossary," in which the terms employed in the text are defined.

We warmly recommend the book to Botanists, Zoologists, Cytologists, and Geneticists alike, to all of whom it should prove of supreme interest, and we congratulate the author on having produced it.

F. W. R. B.

Problems of Relative Growth. BY JULIAN S. HUXLEY. [Pp. xix + 276, with 105 illustrations.] (London: Methuen & Co., 1932. Price 12*s*. 6*d*. net.)

IT is a matter of common observation that the organs and limbs of an organism do not always increase in size at the same rate as the organism taken as a whole. Striking examples of this are to be seen in the large chelæ of the fiddler crab and the antlers of deer, which increase in size much more rapidly than does the rest of the body. This so-called heterogonic growth results in obvious change in the form of the organism which may be progressive during the growth period or may be discontinuous.

Starting from the assumption that the rate of growth of any organ is proportional to a specific constant β which is characteristic of the organ, to the size y of the organ at the time, and to a general factor G which is dependent upon age and environment and is the same for all parts of the body, Prof. Huxley shows that if x be the size of the rest of the body—

$$\frac{dy}{dt} = \beta y\mathrm{G} \text{ and } \frac{dx}{dt} = \alpha x\mathrm{G}$$

where α is a specific constant characteristic of the rest of the body, from which it follows that—

$$\log y = \frac{\beta}{\alpha}\log x + \log b, \text{ or } y = bx^k$$

b and k being constants.

Prof. Huxley first tests this empirical formula by means of quantitative data drawn from a wide range of organisms, and he endeavours to show that there is a constant partition coefficient of growth intensity between an organ, appendage or limb, and the body as a whole over long periods of an organism's life. In the applications of the formula to actual data the time factor is not taken notice of, but only the changes in the relative size of parts of the body with increasing size of the whole, and it may therefore be that the rate of growth is not the factor which is regulated, but that there is some natural limit to the size to which an organ can grow in proportion to the size of the rest of the animal, which limit is the important controlling factor from which the rest follows. For this interpretation there is a good deal of evidence.

It is then shown that differential growth of an organ or limb is not characterised by a uniform distribution of excess growth potential throughout this part, but by a growth gradient in one or more directions from a centre of high growth potential situated within or at the extremity of the organ or limb. These growth laws, if such they may be called, only appear to operate during the later stages of growth after histological differentiation has been completed. Accretionary growth, in which the new material deposited is itself incapable of further growth, gives rise to structures of special types, such as the logarithmic spiral seen in Nautilus and some Ammonites which arises naturally from a uniform growth gradient combined with this mode of tissue formation.

Prof. Huxley then discusses the obscure physiological mechanism underlying these general principles of growth and their bearings upon the theory of evolution. Although it must be admitted that a good deal of the quantitative data could be equally well fitted to other empirical formulæ, a good case has been made out for further study of the one employed in this work because of its usefulness. Apart from this the discussion, around a considerable collection of quantitative material, of the whole subject of size regulation of parts of an organism in relation to the whole renders the work an important contribution to biology.

B. G.

The Social Life of Monkeys and Apes. By S. Zuckerman. [Pp. xii + 357, with 24 plates.] (London: Kegan Paul, Trench, Trübner & Co., 1932. Price 15*s*. net.)

This new volume in the *International Library of Psychology* is based essentially on the author's own researches into the physiology and behaviour of apes and monkeys at the London Zoo, particularly the baboons of Monkey Hill; field observations on baboons in South Africa are also included. But the scope of the book is somewhat wider than the title would suggest. Holding, as he does, that social behaviour "is determined primarily by the mechanisms of reproductive physiology," Dr. Zuckerman has given a full and careful survey of the present state of knowledge regarding the physiology of reproduction in mammals generally and its repercussions upon behaviour, with a view to elucidating just how the primates, which are predominantly social, differ from the lower mammals. In general it may be said that the female of the lower mammal comes on heat and is capable of mating only at periodical intervals, while the primate female, though exhibiting some periodicity, is at all times attractive to the male. "It is important to recognise," writes Dr. Zuckerman, "that the sexual behaviour of the primate is uninterrupted, reflecting the more or less continuous activity of the hormone œstrin. Female monkeys and apes do not periodically experience the abrupt transition from a sexual to a non-sexual state that is undergone by the lower mammal. Both male and female primates are always sexually active to some extent, their heterosexual interests providing the bonds that hold them together in permanent bisexual associations. It is in this that primate society differs from the associations which may be formed by those lower mammals that breed at all times of the year. In these associations the link between the male and female is constantly broken and remade. Sexual bonds become obvious only at œstrous periods that are separated from each other by phases of pregnancy and nursing. The male lower mammal is not stimulated sexually by a pregnant or lactating female, whereas the primate may be. The primate family consists of male, female or females, and young, but the family of the lower mammal consists only of the female and her young" (pp. 146–7).

This thesis is illustrated and supported by numerous facts drawn from a thorough study of the literature and from personal observation. A very full and interesting account is given of the behaviour of the baboon colony in the Zoo, which seems, however, to have been rather abnormal in containing a surplus of males, a circumstance which led to a series of vicious and repulsive "sexual fights." The twenty-four photographs included relate to this colony, and give a vivid picture of the daily life and behaviour of these animals.

The book is a very valuable contribution to the study of reproductive behaviour in general, and of sexual behaviour in apes and monkeys in particular. It is very fully documented; there is a rich bibliography, covering the psychological as well as the physiological literature; it is therefore of value as a storehouse of facts, in addition to its interest as a presentation of the author's own views. The psychological part of the theme seems to us to suffer a little from the aridity of the behaviouristic point of view which Dr. Zuckerman feels compelled to adopt.

E. S. Russell.

A Short History of Biology. A General Introduction to the Study of Living Things. By Charles Singer. [Pp. xxxv + 572.] (Oxford: at the Clarendon Press, 1931. Price 18*s*. net.)

Of the books dealing with the history of special sciences, those devoted to biology are perhaps the least satisfactory. This is largely due to difficulties inherent in the nature of the subject. During the greater part of its history, biology suffered in a special degree from a lack of such comprehensive prin-

ciples as have given, say, to astronomy and physics a more or less systematic character over a comparatively long period of time, even when those principles were subsequently shown to be inaccurate in some ways. In histories of biology one is only too often treated to a considerable number of rather detached accounts of distinct investigations. There are comparatively few books in any language in which the story of biology is related in a sufficiently coherent manner to enable the reader to see the wood as well as the trees. Dr. Singer's *Short History* is certainly one of these few books. The English translation of Eric Nordenskiöld's *History of Biology* (1929) is another. And English readers interested in the subject can do no better than study these two works together. For they supplement each other very usefully and instructively. Whereas Nordenskiöld's account gives mainly a simultaneous presentation of all the biological investigations of each period, Dr. Singer's method consists chiefly in tracing separately the story of special problems and their solutions.

Dr. Singer has made his task peculiarly difficult by attempting to teach the science and the history of biology at the same time. The idea of teaching science, any science, historically is excellent. But it is much more difficult than to teach the science alone or the history alone. And the further attempt to teach both subjects " in simple language " is certainly a laudable ambition. One can only say, and say it gladly, that Dr. Singer has accomplished his difficult task admirably—so admirably that it would be unfair to stress any of the small defects, or dubious matters, that may be found in his pages. And the numerous and excellent illustrations which adorn the book are as valuable as they are helpful.

The work is divided into three parts. Part I is devoted to " the older biology " from Hippocrates and Aristotle to Vesalius and Harvey. Part II deals with " the historical foundations of modern biology," and discusses historically such general topics as scientific induction and scientific instruments, scientific classification and nomenclature, the geographical distribution of plants and animals, and the problems of evolution. Lastly, Part III explains the emergence of the main themes of contemporary biology, namely, cell and organism, vital activity, relativity of functions, biogenesis, individual development, sex, and heredity. The general plan of the book shows that the author has no undue reverence for merely antiquarian lore, and that he treats the history of the past mainly as an aid to the elucidation of the present.

Dr. Singer's occasional digressions into the *general* history of science and even into some of the problems of philosophy may strike some as not altogether relevant or felicitous, but others are just as likely to enjoy them. Here are a few suggestions to be considered when a new edition is called for. The addition of a subject index would be welcome. So would a few small additions to correct such loose ends, *e.g.* as the explanation of Van Helmont's *archæus* by reference to Aristotle's *unexplained* " entelechy " ; or the explanation of the terms *genus* and *species*, while dealing with sixteenth-century biologists, without indicating whether the terms had such meanings at that time already. The view that Aristotle was an evolutionist should be deleted. These, however, are small matters. The book as a whole may be confidently recommended to the general reader as well as to the student of biology.

A. Wolf.

Convegni Biologici. 1° Convegno: Biologia Marina. Napoli. Decembre 1931. (Consiglio Nazionale delle Ricerche. Comitato Nazionale per la Biologie e Comitato Talassografico.) Roma. Viale dei Re. [Pp. 147.] (Price L. 15.)

The first of the Biological Conventions instituted by the National Council of Research (National Committee for Biology and Thalassographical Com-

mittee) met at Naples in December 1931 at the Zoological Station, having for its subject Marine Biology. The papers read at this convention are now issued in a neat volume published by the National Council of Research.

These conventions were instituted in order to bring together workers in all biological subjects to discuss general problems and recent research, and it was fit that the first of these should meet in the celebrated Marine Station of Naples in order to concentrate on all the important marine work accomplished and still going on. In his opening words Dr. F. Bottazzi welcomes the delegates, outlines the aims of the conventions, and with special reference to the Naples Station expresses the hope that the meeting may lead to more of his countrymen making use of the splendid facilities for marine work offered to them there. The remainder of the volume is taken up by six papers, all of great interest, which summarise in brief the main subjects in which their authors specialise. The first, by Dr. R. Dohrn, Director of the Naples Zoological Station, treats of its history and work in general; the second and third, by Dr. R. Issel, are on the nature and annual cycle of the marine plankton, and some of its problems. Dr. G. Colosi's contribution is on animal form and its relation to marine life. Dr. G. Brunelli shows the progress of Oceanography and the Fish Industry, whilst Dr. M. Sella deals with the migrations of the tunny and Dr. S. Ranzi with the influence of the ambient on the reproduction of marine animals. All these are very useful summaries of up-to-date research in different countries on the various subjects, and fully justify the institution of these conventions, which it is hoped will continue to meet in such a satisfactory manner, embracing more and more subjects and attended by more and more delegates from still farther afield.

The volume has two excellent portraits, one of the late Antonio Dohrn and one of the late Salvatore lo Bianco, both of whom did so much for the Naples Station.

M. V. L.

A Naturalist in the Guiana Forest. By R. W. G. HINGSTON. [Pp. ix + 384, with 150 illustrations and 16 plates.] (London: Edward Arnold, 1932. Price 18*s*. net.)

THIS delightful book consists of two parts—first, a general account of the Oxford Expedition to British Guiana in 1929, and second, a series of chapters on certain features of the natural history of the region which specially appealed to Major Hingston. British Guiana was chosen because it provided a good example of a tropical rain forest, and the main objective of the expedition was to study the tree canopy which is formed by the tops of the larger trees at an average height of some 130 feet. Various devices were tried to get a footing in this upper world, and with the help of the natives it became possible to haul up observation chairs to the top of the canopy and to make observations from them. Collections of insects were made by means of traps suspended at different levels. For the full results we shall have to await the scientific reports on the expedition, but Hingston calls attention to one general result which has already emerged, namely, that the forest exhibits a definite horizontal zonation or stratification as regards both the vegetation and the animal life. Hingston gives a very vivid description of the forest at its different levels, and a lively account of the efforts which the expedition made to become acquainted with its teeming life. There are a number of excellent photographs in this section of the book.

In the second part Hingston describes in detail, and with illustrative diagrams, protective devices in spiders' snares, new and strange forms of snares, protective resemblances in spiders and insects, caterpillar cases, modes of nest suspension by birds and spiders and insects, and a number of other interesting natural-history facts. He is greatly impressed by

the widespread occurrence of protective resemblance. "Every now and then," he writes, "as we walk under the canopy a moth, invisible in its natural lurking place, leaps up at our feet as if it were a dead leaf sprung into life. There are other grey kinds which settle on pale-coloured bark, others with green and yellow patterns that exactly blend with moss and lichen. Others, like *Therinia*, which rest flat on leaves where they are mistaken for the excrement of birds. The stick-like Mantids and leaf-like Phasmids, some kinds green, others withered, though so well known, yet never fail to make one reflect on the staggering perfection of their harmonisations. As though unsatisfied with being the detailed image of a leaf, some kinds sway themselves gently and irregularly so as to imitate the leaf swinging in the wind. . . . There are literally thousands and thousands of insects which illustrate in structure, habit, pattern, and colour the universal law of harmony" (pp. 82–3). The curious zigzag and spiral patterns, the radial thickenings and blobs, which appear on many spiders' webs Hingston regards as protective devices to mislead a possible enemy as to the position of the spider itself.

One feels, with regard to many of these cases, that a few definite experiments would be more convincing than the endless piling up of instances of resemblance which look to us as if they ought to have protective value. In particular one would very much like to know whether these resemblances and devices appear to other animals as they do to us, whether the bird and insect enemies of the forms in question perceive and are deceived by the resemblances which to us are patent. We cannot safely assume that these enemies have the same perceptual world as ourselves. There is here great room for experimentation. It is indeed one of the great weaknesses of the theory of natural selection that the direct experimental evidence in its favour is singularly scanty; its upholders have depended very largely upon abstract reasoning to establish its existence, but here an ounce of experimental fact would be worth many pounds of logic. The question of interpretation does not, however, affect the value of the numerous and interesting facts which Hingston sets out in his book. As a study in animal ecology and behaviour the book has permanent value.

In an Appendix twenty-seven new species of spiders are described.

E. S. Russell.

MEDICINE

The Physical Mechanism of the Human Mind. By A. C. Douglas, M.B., Ch.B. [Pp. xiv + 251.] (Edinburgh: E. & S. Livingstone, 1932. Price 15s.)

The title of this book indicates very clearly its purpose. The author sets out to demonstrate that a complete scientific theory of mind may be presented upon a materialistic basis, being convinced that Dualism with introspective analysis as its sole method of investigation is incapable of leading to an understanding of the problem.

The opening chapters contain some general considerations as to the relation of Mind and Matter and of Life and Mind, from which it is concluded "that increased potentiality of mind emerges *pari passu* with increased complexity of organic structure, and cannot be otherwise attained." The author then gives a simple, but sufficiently adequate account of the findings of modern physiology as to the properties and modes of action of muscle and nerve, which lead him to believe that the only factor concerned in the propagation of a nerve impulse is a physico-chemical change. Lapicque's theory of chronaxie, which offers an explanation of many of the physiological results of muscle and nerve activities based on such changes, is followed with some detail. It would have been satisfactory to have had from the author an equal consideration of Sherrington's humoral theory, which is not open to

the criticisms which have been applied, as he himself points out, to some of the details of Lapicque's theory. The author, however, has clearly been most concerned to show that given a certain set of physical conditions in the nerve, alterations in these would lead to precisely those effects which are found in physiological reactions.

In the next section of the book he shows by ingenious and helpful diagrams how the complexities of the nervous system have been gradually developed from the initial simple connections. Having thus established the structural physiological bases of his theory, he then turns to the construction of a scientific synthesis which will cover the chief manifestations of mental activity. Attention, perception, association, memory, thought, knowledge, belief, reason, will, and imagination are all discussed in terms of the physiological findings. The development of speech and symbolic thought are also explained upon similar lines. A final chapter on the limitation of mind brings to an end a book which gives a well-reasoned and clear statement of a very complicated subject. No book dealing with this particular problem can be exactly light reading, but the author builds up his case so gradually, and illustrates his argument with actual cases so skilfully, that whether he convinces his reader or not, he will certainly rouse his interest, and that probably to an increasing extent as he reads.

W. C. C.

The Extra Pharmacopœia of Martindale and Westcott. 20th ed. Revised by W. HARRISON MARTINDALE. Vol. I. [Pp. xlviii + 1216.] (London: H. K. Lewis, 1932. Price 27*s*. 6*d*. net.)

IT is appropriate that this twentieth edition of the *Extra Pharmacopœia* should appear to celebrate the Jubilee of the publication of the first Edition in 1883, prepared by the son of one of the original authors. From the slim volume of 313 pages of fifty years ago it has become a two-volume work, of which the present first volume comprises no less than twelve hundred and sixty-four pages, only saved from unwieldiness by the use of admirable small type and thin paper.

The character of this indispensable work of reference is too well known to require commendation, and it will suffice to say that the resetting of the type has rendered the text admirably clear.

E. J. S.

MISCELLANEOUS

Sailplanes. By C. H. LATIMER NEEDHAM, M.Sc. [Pp. xx + 268, with 196 figures.] (London: Chapman & Hall, 1932. Price 15*s*. net.)

THE science and practice of gliding has made great strides in the last ten years, mainly in Germany. Nowadays, when it is the fashion to decry the Treaties of Versailles and Trianon, it is perhaps only just to point to one science and industry which would probably not have been evolved without the restrictions on the building of power-driven aircraft, which their framers imposed on the Central European Powers—with results which they certainly did not anticipate. The construction of motor-less aeroplanes, at first as models and then as manned gliders, and the study and use of the vertical convection currents up mountain sides and under rain clouds was brought to a fine art by the members of the Rhon-Rossitten Gesellschaft under Dr. Georgii. Their methods are now being copied and improved upon by branches of the British Gliding Association.

The first two parts of the book deal with the design and construction of gliders. Naturally, most of such matter is common ground with aeroplane design, but the requirements of strength and stability with lightness particular to this type are carefully considered. Details of successful types are

included. In the third, and, perhaps, the most interesting portion of the work, the author gives an outline of glider dynamics. The methods of taking-off and soaring in albatross fashion are clearly explained. Incidentally, here is another possible use for the new mode of propulsion by rocket, *i.e.* to give the impetus to get a glider off the ground, and into the convection wind.

A number of appendices contain useful data and regulations for sailplane builders and users. Altogether, this book is a very informative and well-produced treatise on current English and German glider practice. Dr. Magnan's work in France on bird flight is not mentioned, but should find a place in a subsequent edition, as it laid the foundation of experimental glider research.

E. G. R.

The Calculation of Heat Transmission. By MARGARET FISHENDEN and O. A. SAUNDERS. [Pp. xii + 28.] (London: H.M. Stationery Office, 1932. Price 10*s.* 6*d.* net.)

THE authors of this book, as explained by Sir Richard Threlfall in a foreword, were commissioned by the Fuel Research Board to write an account of the present state of knowledge of radiation, conduction, and convection, more particularly on the experimental side. This report is but a preliminary to a thorough investigation of the scientific principles which should underlie the design of furnaces. It will be evident, from a reading of this book, that such an investigation is very necessary. Research on the subject up to the present has been mainly empirical, and the work has not been co-ordinated—each investigator dealing with the little problem at hand—and often the results of different investigators seem conflicting. A good deal of useful information does emerge, however, from the survey which the authors have presented in the convenient form of a series of graphs. The value of the work is enhanced by worked examples employing the data which are given. Naturally, dimensional methods are freely employed.

The authors seem to have purposely passed over papers dealing with determinations of thermal constants, but we think that a mention at least of such work would have been an advantage in such a treatise, as much of the information gained in such academic research is of direct use to the engineer.

A well-arranged subject-index enables the engineer to find quickly the data relevant to any problem with which he has to deal, but the book could have been improved by the addition of critical summaries to the mass of data presented under each type of transmission.

E. G. R.

Vital Records in the Tropics. By P. GRANVILLE EDGE. [Pp. xi + 167, with 1 plate.] (London: G. Routledge & Sons, 1932. Price 7*s.* 6*d.* net.)

ON the cover of this small volume we are told that it is "no dry-as-dust textbook," and further acquaintance with it confirms that view. It would be easy to advocate the immediate establishment in tropical countries of elaborate census and registration systems similar to those now in use in European countries. It would be about as useful to advocate the instalment of an automatic telephone system in Central Africa. It must be remembered that these systems are only successful where the people have been gradually educated to be both able and willing to give the information asked for. There are some countries, including at least one in the tropics, where the attempt to tabulate causes of death under the international code of diseases at present merely results in large volumes of misleading and inaccurate figures. Mere compilations of statistics collected by unsympathetic officials from a suspicious and ignorant populace who have no understanding of the reasons for making the inquiry nor accurate knowledge of the answers to be given is a thankless and useless task. The better course is to work from simple begin-

nings, aiming at convincing the people step by step of the benefit which accrues to themselves of obtaining accurate records of the vital events in their family and tribal life. It is in this way that our own system of vital registration has been built up.

Mr. Edge attempts in this book to enlist the interest of administrators in the task of constructing systems of vital registration on such foundations, taking into account the conditions and state of civilisation of the people concerned. To quote from his prefatory note, "The introduction of small-scale inquiries should aim first at securing the voluntary co-operation of limited groups of people. With the extension of such inquiries, accumulated experience will indicate more surely what, and when, legislative measures might be introduced, compelling for the territory as a whole a course of action to which a large proportion of the population had already been subscribing by voluntary effort." Hasty and ill-considered attempts to secure elaborate vital statistics relating to undeveloped areas may only, he points out, "impede rather than accelerate ultimate success in this field of work." His attempt deserves success, for he writes, not only with an understanding of the conditions of life in tropical countries and of the natural prejudices of the natives against official inquisitiveness as to their private affairs, but also with an enthusiasm and wealth of common sense.

Three chapters are devoted to methods of census taking, and in these he rightly emphasises the importance of carefully selecting and training the native enumerators, a lesson not fully learnt even in our own country until the recent census, when an attempt to utilise the services of unemployed men led to grave difficulties. Useful suggestions are made as to how the prejudices of the populace may be overcome and an approximate grouping by ages obtained. Vital registration of births, deaths, and disease are then dealt with, a point of special interest being the suggestion of a practical method of securing records of births and infant deaths by means of attractive metal discs to be worn as ornaments as long as the child survives, and then returned.

Several chapters are finally devoted to methods of presentation of the data secured, a short list of fifty most important causes of death in tropical countries being suggested, which can be correlated with the international code of nomenclature.

Mr. Edge's work can be recommended as a useful handbook for all who are interested in the compilation of vital records of tropical countries.

β_4.

At Home with the Savage. By J. H. Driberg. [Pp. x + 267, with 17 illustrations.] (London: George Routledge & Sons, Ltd., 1932. Price 7*s*. 6*d*. net.)

The author of this book has had fifteen years' service as District Commissioner in Uganda and the Sudan. He says that he had received no training whatever in anthropology before going to Africa, and he was then entirely unacquainted with the literature of the subject. Mr. Driberg is concerned here, as in his earlier works, with illustrating the wrongness of such a position and providing information which should make it impossible for any future administrator of primitive peoples to be similarly situated. Administrators must have an adequate knowledge of the native cultures with which they are brought in contact before they can hope to serve the best interests of both the rulers and ruled. This has often been said in recent years, but there still seems to be a need for the lesson to be repeated in order that it may be effectively acted on.

At Home with the Savage gives an interesting introduction in non-technical language to the customs and beliefs of primitive peoples in general. Such topics as the standpoint of the individual, the organisation of the family, of the clan and of larger groups, warfare, education, religion, and economic life

are dealt with in turn. The writer stresses the point that only facts matter in so far as the practical politics which he has at heart are concerned, and he goes out of his way to assert that sociological theories, physical anthropology and archaeology are of little practical relevance to-day. It is almost implied that these more academic aspects of anthropology are never likely to be of any importance to those who govern backward peoples, but such a view may well be contested. Nothing is said of the obvious importance of demographic and medical statistics, and one may hope, at least, that physiological and eugenic data will ultimately give valuable guidance in the connection considered. The difficulty of obtaining information of this kind is illustrated by an account of the order of a well-meaning Government that births should be registered. A registration fee was imposed, and this was so much resented by the natives that the women left the villages at the time of delivery and the children were born in a neighbouring mountain region. "There they died in hundreds, and a measure introduced nominally to benefit the community would, if enforced, have led to its extinction." The epilogue to this book consists of a number of stories similar to this one illustrating the errors that may be made by officials who are ignorant of native customs. It is not claimed, of course, that this volume is a sufficient guide to social anthropology for the purposes of the district officer. The cultures of even neighbouring primitive peoples are often found to be essentially different in many respects, and an incomplete acquaintance with a particular one may be as dangerous as none at all. The administrator must make an intensive study of the people of his own district, both by reading and observation in the field, if the justice he dispenses is to be even-handed. The plates are of natives and native surroundings in various parts of the world, and several of them seem to bear little relation to any matters dealt with in the text. One, for example, is a reproduction of a male and a female reindeer carved in ivory in prehistoric times.

β_s.

Introduction to Theoretical Seismology. Part II, Seismometry. By F. W. Sohon, S.J. [Pp. viii + 149.] (New York: John Wiley & Sons; London: Chapman & Hall, 1932. Price 16*s.* 6*d.* net.)

There is no sharp line of demarcation between theoretical and practical seismometry, inasmuch as practical considerations usually decide what theoretical investigations are necessary; personal preference must therefore partly settle what is to be called "theoretical." Few, however, are likely to disagree with Fr. Sohon's choice of material and his treatment; the work is not a mere uncritical compilation, but is written by an experimentalist who knows both how his instruments should behave and how they do behave. The treatment may be called theoretical, perhaps, because it does not refer to such practical considerations as spiders' webs, but the experimentalist need not fear that all he will learn is the theory of types of instruments that he is not interested in.

The discussion is necessarily mathematical in many places, but the conclusions and formulæ are clearly stated, and the mathematics is intelligible to readers of quite moderate mathematical attainments, without being of the cumbrous type often employed with a view to "simplifying" the treatment. Nomograms are given for Galitzin magnification and for computing epicentral distances. Tables have been computed of a number of useful quantities, and a critical table is given to facilitate corrections for clock rate.

The discussion of friction includes a valuable exposition of the theory of stylus-friction, and it is shown how to disentangle from a decay-curve the effects of solid friction and of fluid friction; such treatment ignores friction depending on the square of the velocity, but Fr. Sohon does advise that any viscous damping devices should be so adjusted that, effectively, ordinary

viscosity predominates over eddy viscosity. The Galitzin seismograph, with the tapping test, naturally occupies a good deal of the available space. In a short but important chapter devoted to the onset of a new phase, the Berlage, Benndorf, and Galitzin methods of representing the onset are explained.

It is inevitable that in a work occupying only 149 pages, including the index, something has to be sacrificed. It is unfortunate that adequate references are not given, or, failing that, a bibliography. As it is, the reader is given no means of following up various topics that may appeal to him, and he is even invited to look up a paper by Wood and Anderson (p. 62) without being told either the title or the publication. The section on "Forms of Suspension" on p. 23 could have been usefully illustrated by diagrams.

The number of misprints noted is not large; the following may be mentioned:

P. 58. Equation (65), for x read $\ddot{x}$.
P. 65. In the line following equation (87) the second U should be u.
P. 69. Diagram. The top ordinate should be 3T/2 not 3T/T.
P. 77. In equation (109) a ϕ has been written for $\dot{\phi}$.
P. 94. Equation (154). The bar should not extend over kA_1T.
P. 95. Equation (157). For 0·7689 read 0·7698.
P. 128. The curve marked S,S should be marked P,SS,P. The S,S curve has been omitted.
P. 134. It should be stated that the circle is of unit radius.

It ought to have been mentioned that according to equations (77) on p. 62, pw is between 0 and π, and the same condition should be used to remove the ambiguity in equation (98) arising from the use of the many-valued function arc tan. Actually this definition is given later on (p. 97), but in a special problem, and after the reader has presumably worried out the point for himself.

The type is clear, the paper good, and the arguments well set out. Even those seismologists who have little to learn from the book (and these will not be many!) will find it a valuable reference-book, and its perusal should suggest further lines of investigation.

R. Stoneley.

Pistol v. Poleaxe. A Handbook on Humane Slaughtering. By Lettice Macnaughten. Foreword by Viscount Lee of Fareham and Preface by Prof. R. G. Linton, Ph.D., M.R.C.V.S. [Pp. 164.] (London: Chapman & Hall, 1932. Price 21*s*. net.)

In twenty-five years of persistent and reasonable advocacy of reform in the methods of slaughtering animals for food, Miss Macnaughten has acquired a considerable mass of information which she has summarised in this book. It is a weighty volume because Miss Macnaughten has endeavoured to present the views, apart from their quality, of everyone who has discussed the methods of slaughtering cattle, sheep, pigs, and calves, Jewish and Mohammedan methods of slaughter, slaughtermen, slaughterhouses, humane killers, and legislation. Mr. L. M. Douglas has contributed a chapter on stunning-pens and pig-traps.

A distinguished, authoritative, and fervent worker for the relief of animal suffering, Miss Macnaughten is most informative and convincing when writing on the morals and ethics of her subject. The text and the ninety-five carefully selected illustrations, some of the latter being a shade "overdone," conclusively prove that her case is morally and ethically sound. Unfortunately, her conclusions are not clearly stated, but they are implicit in the text provided the general reader is prepared to sift a great mass of observation and surmise, with which the book is overloaded. However, the evidence

shows that the technique of converting cattle, sheep, and swine into beef, mutton, and pork is very complex, although the essential act (*i.e.* slaughter) is relatively very simple. There is only one criterion for the destruction of life by civilised man—the act must be instantaneous. If only this obvious criterion had been accepted as the basis of private and public discussions, a great deal of discord would have been prevented and Miss Macnaughten's book would have been much smaller and more readable. Slaughtermen and meat traders are a fair sample of the general population, and naturally they resent the implications of the term "humane" being applied to their work. In the mouths of many uninstructed "humanitarians," careless of human susceptibilities, the word "humane" can be made very offensive. Even the title of this book has not been happily chosen. It would appear improbable that any method of slaughter will give universal satisfaction so long as economic criteria are weighed against those of the humanitarian; but some progress might be made if instantaneous destruction be accepted as the guiding principle.

Miss Macnaughten is not so successful when handling such highly technical subjects as the factors affecting the keeping qualities of meat, "splashing," etc. Accurate definition of these problems is not materially influenced by observation and surmise of meat traders, justices of the peace, borough councillors, and so forth; it can only result from the controlled experiments of competent biologists. Science should now be called in to complete the great work which will ever be associated with Miss Macnaughten's name. Her book is of great value for its wealth of information and for its teaching that though the end be ideal, the means of attaining the end on behalf of animals and man must be practical.

TOM HARE.

Fresh Water. A History and a Narrative of the Great Lakes. By G. A. CUTHBERTSON. [Pp. 316, with illustrations.] (Toronto: The Macmillan Company of Canada; London: Macmillan & Co. Price 36*s*.)

THE aim of the author is to present a history of the ships which navigated the Great Lakes so as to include their development with political and geographical developments, from earliest times to the present day. Good use has been made of previous studies, such as those of Mahan, Parkman, Grant, Cruikshank. The author has also availed himself of official documents, English and French, and thus has enhanced the historical value of the work.

The development of the Great Lake region and of the interior of the continent, of the mineral wealth and the conversion of this waterway into a commercial highway are all matters of international importance. The evolution of this great commercial highway and the historical struggles in North America have been made of great interest. The illustrations, which number over thirty, are admirably chosen to aid the text, and their artistic value too will be appreciated.

The historical matters are treated vividly with careful regard to accuracy and fairness. The final chapter of this interesting book deals with the rise of the shipping companies now engaged in transportation on the Great Lakes. It seems unfortunate that the wealth of detail provided does not include any trade returns or statistics of cargoes carried. May the reviewer suggest that some such details, together with port returns, might make yet another appendix? It is unfortunate that a few blemishes are to be found in the compiled bibliography and in the names of one or two French ships. The index, however, is full and reliable.

The book makes very pleasant reading and will be appreciated by a wide circle of readers, amongst whom will be included the historically and geographically minded.

J. ELING COLECLOUGH.

Science and Human Experience. By Herbert Dingle, Assistant Professor of Astrophysics, Imperial College of Science and Technology; Hon. Secretary, Royal Astronomical Society. [Pp. 141.] (London: Williams & Norgate, 1931. Price 6s. net.)

This volume contains the substance of four lectures on "The Nature and Scope of Physical Science," which Prof. Dingle delivered at the Royal Institution in 1931, and an additional chapter on "Science and Religion." Here we have, if not exactly a confession of faith, then at least a philosophy of science and a good deal besides. Scientists, and astronomers more particularly, have in recent years written a great deal on philosophy. It is not always very clear where precisely they draw the line between their science and their philosophy. One sometimes has the feeling that what they understand they call science; what they don't understand they call philosophy. Naturally, there is ample room for such philosophy; and one ought to feel grateful to those who have the courage to think aloud about such problems. Considering its small size, this book has a remarkably varied and attractive list of contents, ranging from the birth of modern science to relativity and the quantum theory, and including such fascinating and contentious topics as the relation of science to art, to literary criticism, and to religion. And on all these themes the author writes in a way that should interest the general reader as well as the student.

There is only one criticism I shall venture to make, and even that one I make with some diffidence. It seems to me that Prof. Dingle's use of the terms *experience* and *conception* is rather ambiguous, possibly confused, and that the lack of sufficient clarity in his use of these terms, which constitute the key to his philosophy of science, obscures or even undermines his exposition of his main theses. "By experience (he writes) I mean everything of which we are conscious except rational conceptions. I think of consciousness as composed of reason, on the one hand, and all sensations, feelings, emotions, passions, and the like, on the other; the latter constituting what I mean by experience." This may seem clear and unobjectionable. But it soon appears that Prof. Dingle does not distinguish between experience, as such, and the object of which it is an experience. Thus, for instance, he describes physical objects, God, etc., as "experiences." Now, to normal people the physical objects of which they have experience always appear to be distinct from, and even independent of, the experience which they have of them—in fact, they are much more aware of the *objects* than of their *consciousness* of the objects. The identification of the two calls for some justification. It is not self-evident that an object of experience must itself be an experience. Similarly, when Prof. Dingle denies that "illusion" has any meaning for science, this can only be on the ground that one experience, *qua* experience, is as real as another. For instance, the visual experience of a stick bent in water is as real as the tactual experience that the stick is straight. But usually people are not concerned with experiences as such, but with the *objects* of their experiences, and thus regarded, the bent stick is an "illusion," the straight stick is not. The fact that the apparent bending of the stick can be explained by the laws of refraction does not do away with the illusion, for only the rays are bent, not the stick. The same ambiguity haunts Prof. Dingle's use of the term *concept*. No distinction seems to be drawn between the conception (or idea) of an object and the object conceived. When electrons and protons are said to be "pure conceptions," does this mean that they are actually ideas, or only that we must think of them through ideas and cannot perceive them? If the former, then the view needs justifying. It is not self-evident that what is conceived by means of a concept must itself be a concept. Again, does Prof. Dingle really mean to identify the laws of Nature (that is, the alleged regularities of natural events) with their verbal formulæ? Sometimes, indeed, Prof. Dingle writes as though he embraced Vaihinger's philosophy of

"as if," that is, the view that scientific explanations are not intended to suggest more than that things behave "as if" there were electrons, etc. But there are other passages which do not bear such an interpretation. Of course, if Prof. Dingle accepts "experiences" and "concepts," as such, for his ultimate realities, then he cannot escape from the kind of idealism which Eddington and Jeans embrace. But all three seem to me to suffer from the same kind of philosophic confusion. Prof. Dingle's treatment of causality and symbolism tends to confirm the suspicion that his book is lacking in clarity of philosophic thought, although it has many good qualities.

A. Wolf.

Economics in Primitive Communities. By Richard Thurnwald, Professor of Ethnology and Sociology in the University of Berlin. [Pp. xiv + 314.] (Oxford University Press for the International Institute of African Languages and Cultures, 1932. Price 25*s*. net.)

Economics in advanced communities is a study of vital importance to-day, and any aid which it may be possible to give it should be welcome. One might anticipate that a study of the economic life of primitive communities would at any rate offer simpler problems for solution, and that the principles deduced from its data might possibly aid in the analysis of more complex conditions. Even in this field, though, it appears that different authorities find it difficult to reach any real agreement. This book opens with the statement that the theory of three stages—a hunting leading to a pastoral and thence to an agricultural—which was once generally accepted, must be rejected entirely because it does not accord with the facts. It is said that the idea of development along a single line does not help in these matters. In each primitive community all activities of life are harmonised into a complete whole, and different aspects of it cannot be separated and considered in isolation. The complexity of the problems to be solved must be realised from the beginning. Economic systems are determined by the interplay of geographical and social conditions, and psychological traits must also be considered. Having prepared his readers to expect no simple generalisations, Prof. Thurnwald deals with different aspects of the subject in detail, dividing his survey into the three sections: "conditions of primitive economics," "types of economic life," and "forms of economic activity." A bibliography is appended, and he refers constantly to the first-hand descriptions of primitive societies in different parts of the world given in the sources cited there. By far the greater part of this book is taken up with the presentation and comparison of this detailed evidence, and the reader may well be confused by such a wealth of material exhibiting such diverse features. It is concluded that economic and political organisations are connected in a peculiarly intimate way, and that the evolution of these aspects of social life must be traced together. It is impossible to summarise in a few words the many minor generalisations which are brought forward. Several of the anthropological and sociological terms used are defined in a preface, but no definitions are given of the economic terms, such as "money," and in the case of several of these it might be difficult to decide how Prof. Thurnwald would define them. It is not clear that a study of this kind would aid the economist in his efforts to solve practical problems, but it is bound to be of far greater interest to the cultural anthropologist. Diagrams are given illustrating the development of economic methods and simple technical skill.

β_s.

The Last Cruise of the "Carnegie." By J. Harland Paul. [Pp. xvii + 331, with 198 illustrations.] (Baltimore: The Williams and Wilkins Co. London: Baillière, Tindall & Cox, 1932. Price 26*s*. 6*d*. net.)

Here is a record of the seventh and last voyage of the *Carnegie*, the ship belonging to the Department of Terrestrial Magnetism of the Carnegie

Institution of Washington, built, in 1909, entirely of non-magnetic material for magnetic and electrical survey work. By the end of the sixth voyage, which terminated in 1921, the *Carnegie* had sailed nearly 300,000 miles and had provided a complete magnetic survey of the oceans of the earth. The programme of the seventh cruise, which began on May 1, 1928, included an elaborate oceanographic survey and a series of magnetic observations directed to determine the secular changes in the magnetic elements. Half the programme had been completed and 52,000 miles traversed when, on November 29, 1929, the ship was destroyed by a petrol explosion at Apia, Western Samoa, Captain Ault, the commander and chief of scientific staff, and the cabin boy losing their lives.

Dr. Paul, the surgeon and observer for meteorology and oceanography, gives us a fascinating account of the human aspects of the work on board, of its often arduous labours and of its occasional pleasures, illustrated by a series of photographs which reflect the utmost credit on both photographer and printer. On the voyage many unfamiliar places were visited from Reykjavik to Rano Raraku, from Kakioka to Huancayo, and the author has something of interest to tell us and to show us about them all. Not the least interesting feature for the English reader is the extraordinary contrast between the receptions given to the expedition in England and Germany. At Plymouth it was welcomed by Capt. Arnold on behalf of the Royal Navy, and its members were entertained by Dr. Allen and Dr. Atkins of the Marine Biological Laboratory. Sir Frank Dyson travelled from London to visit them and the Royal Society sent a complete set (sixty volumes) of the records of the *Challenger* expedition. At Hamburg the expedition received an official welcome from the government and many scientific societies, an official host was appointed to look after the needs of the expedition and the entertainment of its members. They were taken to a special meeting of the Geographic and Oceanographic Societies in Berlin, the Deutsche Lufthausa provided an aeroplane for a flight over Hamburg, there were drives, invitations to dinners, operas, and cabarets, and, as Dr. Paul remarks, "No doubt about it—we are welcome in Hamburg." A contrast indeed, though doubtless not without political significance.

A pleasant and modest book containing much material of scientific importance which will not be available in more formal dress for some time to come.

D. O. W.

Cambridge Excavations in Minorca. By M. A. Murray and Others. [Pp. 50, with 52 plates.] (London: Bernard Quaritch, 1932. Price 12*s*. 6*d*. net.)

Surprisingly little, and that of questionable value, has been written in English about the Balearic Islands. Of the antiquities of Minorca, outside Spanish archæological journals not easy of access, the only reference of value is in Cartailhac's *Monuments primitifs des Iles Baléares*, for which no data from excavation were available. Archæologists are therefore deeply indebted to Dr. Margaret Murray for this work on her expedition to Minorca, and to the Curator of the Cambridge Ethnographical Museum by whom that expedition was suggested and financed.

Minorca possesses in the *taula* a form of megalithic monument which is unique. This, as its name suggests, is in appearance a flat table of stone, which is balanced on a pedestal. It is a monument, as a rule, of considerable size. The *taula* of Trapucó, the site on which Dr. Murray was engaged, consists of a slab 12 ft. 4 in. long, 5 ft. 7 in. wide, and 2 ft. 1 in. thick, resting on a pedestal 14 ft. 4 in. in height from ground-level (total height of stone over 16 ft.), 9 ft. wide, and varying in thickness from 1 ft. to 1 ft. 6 in. The upright is fitted into a groove in the rock and also fits into a shallow groove

or mortise in the underside of the slab. The slab is most carefully worked, more so than the pedestal, and its edges are bevelled, thus reducing the area of the underside considerably. The *taula* is always associated with one or more *talayots*, the peculiar stone towers of the Balearics, which Dr. Murray suggests were prehistoric farmhouses.

In this first part of her account of the excavations at Trapucó Dr. Murray describes the clearing of the temenos surrounding the *taula* and of the adjacent structures, and the uncovering of the *taula*, of which previously very little was to be seen above the accumulations of vegetation, rubbish, and stones. Pottery, objects in stone, bone, bronze, and iron were discovered. All these are carefully described and figured, Dr. Murray's conclusion being that the monument belongs to the early bronze age, that it was hypæthral, and that the purpose of the *taula* was to serve as a cult object, and not as either an altar or a roof support, as Cartailhac suggested.

Dr. Murray and her colleagues, of whom Dr. Edith Guest describes the human skeletal fragments found in the adjacent gallery, are to be congratulated on a careful piece of work, and the thanks of students are due to them for the careful descriptions and the exhaustive and skilfully prepared illustration of the objects found.

Correspondence and Papers of Edmond Halley. Arranged and Edited by E. F. MacPike. [Pp. xiv + 300, with 11 illustrations.] (Oxford: Clarendon Press, 1932. Price 21*s*. net.)

We much regret that it is not possible in the April issue of Science Progress to give this very notable contribution to the literature of the history of science a review worthy of its interest and importance, but we hope that it may be possible later on to consider it in detail. Publication was rendered possible by a grant from the History of Science Society from funds allotted to them by the Carnegie Corporation of New York, but the work itself is the result of many years' research by Mr. Fairfield MacPike of Chicago, aided by the enthusiasm of many collaborators in this country, notably Mr. A. H. White and Mr. H. W. Robinson of the Royal Society, to all of whom full acknowledgment is made. Much of the material used is available only in manuscript form, and none of it is readily accessible, for care has been taken to omit matter found in all well-equipped scientific libraries.

The letters, the unprinted papers, and the *Halleiana* enable the reader to form a vivid picture of the man and of his extraordinarily varied achievements: at 20 going to St. Helena to map the stars in the southern sky; at 30 persuading Newton to write the *Principia* and publishing it at his own expense; at 40 Comptroller of the Mint at Chester; at 48 Savillian Professor of Geometry at Oxford; at 64 Astronomer Royal. Between times assistant secretary of the Royal Society, Commander of H.M. ship the *Paramoor Pink* and Queen Anne's Commissioner in Austria, and at all times communicating papers to the Royal Society on subjects as varied as his career. It is astonishing indeed that no ordered account of his life has yet been written, but Mr. MacPike has provided material which must surely provoke one in the near future.

BOOKS RECEIVED

(Publishers are requested to notify prices)

Elements of Co-ordinate Geometry. By J. M. Child, B.A., B.Sc., Lecturer in Mathematics in the University of Manchester. London: Macmillan & Co., St. Martin's Street, 1932. (Pp. xiii + 468.) Price 10*s*. 6*d*. net.

Foundations of the Theory of Algebraic Numbers. By Harris Hancock, Ph.D. (Berlin), Dr.Sc. (Paris), Professor of Mathematics in the University of Cincinnati. Vol. II, The General Theory. Published with the Aid of the Charles Phelps Taft Memorial Fund, University of Cincinnati. New York: The Macmillan Company, 1932. (Pp. xxvi + 543.) Price $8.00.

Linguistic Analysis of Mathematics. By Arthur F. Bentley. Bloomington, Indiana: The Principia Press, 1932. (Pp. xii + 315.)

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